

SSME ALTERNATE TURBOPUMP DEVELOPMENT PROGRAM (HPOTP)

**VERIFICATION COMPLETE REPORT
FIRST TURBINE BLADE AERODYNAMIC DESIGN
DVS DR NO. 3.1.2.2.5.1, VM NO. 4.1.2.4 A**

JUNE 1989

**Prepared under
NASA Contract NAS8-36801
DRL Sequence No. SE12
WBS No. 1.5.1.2**

**Prepared for
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, AL 35812**

**Prepared by
Pratt & Whitney
P. O. Box 109600
West Palm Beach, FL 33410-9600**



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Approved by:

John Price Jr.
W. C. Shubert
ATD Project Manager

(NASA-CR-183760) SSME ALTERNATE TURBOPUMP
DEVELOPMENT PROGRAM (HPOTP). VERIFICATION
COMPLETE REPORT: FIRST TURBINE BLADE
AERODYNAMIC DESIGN DVS DR NO. 3.1.2.2.5.1,
VM NO. 4.1.2.4 A (PWA) 39 p

N90-70027

00/20 0233348
Unclassified



**UNITED
TECHNOLOGIES
PRATT&WHITNEY**

HPOTP Turbine Aerodynamic Design

The High Pressure Oxidizer Turbopump (HPOTP) turbine aerodynamic design is based on the requirements defined by the Interface Control Document (ICD) and by the Power Balance Model, Table 387B. Performance Table 387B was used for the turbine aerodynamic design because its turbine flow capacities are consistent with the baseline turbine nozzle flow test results conducted on Pratt & Whitney's test stand, E-6, in December, 1986.

A 3-stage turbine was selected over a 2-stage design for three basic reasons:

1. To retain desired efficiency at the reduced pump speeds.
2. To provide adequate performance margin with unshrouded blades.
3. To ensure adequate margins for adjusting to cycle requirements.

A conventional pressure-compounded, 3-stage design was chosen because of its inherent high efficiency with low aerodynamic risk. This aerodynamic advantage allowed the use of unshrouded blades. Unshrouded blades are desirable because they permit the use of PW1480 single-crystal material, which provides superior thermal fatigue characteristics, but at the present state-of-the-art, cannot be easily cast in the form of shrouded blades in this small size. The turbine aerodynamic design provides relatively high velocity ratios, which are within the range of normal design practice and experience. Avoiding lower velocity ratios eliminates excessive gas turning, and the need for blades with excessively small leading edge radii. Blades with sharp leading edges make the turbine intolerant at incidence angle changes resulting from off-design operation. Under such conditions, severe flow separation is common.

The methodology associated with the design of the HPOTP starts with the meanline design analysis. This analysis is based on the assumption that the flow through the turbine can be represented by the flow at the center of the flow passage. This simplified approach permits selection of the number of stages required, the mean diameter of the flow passage, and the annulus area. Included in the analysis is an estimate of the aerodynamic efficiency. This prediction system uses the physical laws of aerodynamics and correlations from rig and engine data to estimate profile loss, secondary loss, blade tip leakage, and shock and incidence losses based on the geometry and aerodynamic parameters of the turbine. An interactive graphic flowpath design system is used, in conjunction with the optimum meanline design, to generate candidate flowpath configurations.

The streamline design analysis is used to optimize the radial variation in the velocity triangles, once the average conditions are selected from the meanline analysis. This analysis calculates the flow characteristics at numerous radial locations and at the inlet and exit of each airfoil row. Once the meanline and streamline analyses have been used to optimize the velocity triangles throughout the turbine, 2 dimensional (2-D) airfoil sections are designed. These airfoil sections are designed to achieve contours that provide the desired amount of flow turning without permitting the flow to separate from

the airfoil surface. This process involves determining the static pressure distributions and boundary layer parameters along the airfoil surfaces and endwalls. An interactive graphics airfoil design system is used to identify adverse static pressure gradients such that the airfoil contour can be modified appropriately. After the 2-D airfoils are estimated at several spanwise locations, they are radially faired and combined with a preliminary endwall definition. An inviscid multi-stage 3-D flow analysis is then used to refine and optimize the entire flowpath configuration.

All turbine airfoil, endwall, inlet, and exit flow passage surfaces are contoured and refined as a system. The multi-stage feature enables a complete evaluation of potential changes to an individual surface contour during the design process. This assessment includes, not only flow property changes around the component being modified, but also around all upstream and downstream components in the complete turbine system. Improved performance and reduced risk result from this global optimization capability.

This report contains:

- o Hot elevation diagrams for each airfoil
- o 3-D airfoil plots
- o 2-D airfoil section plots
- o Tabulated airfoil section coordinates
- o A plot of hot gaging dimensions versus radius
- o A plot of percent change in flow area versus airfoil rotation
- o A plot of stress versus span
- o 3-D airfoil static pressure distributions
- o Airfoil Ps/PT and Mach number contours
- o A plot of suction surface boundary layer friction coefficient versus surface distance

COVER SHEET
SPACE SHUTTLE
ENGINE A.T.P. LOX PUMP TURBINE
AIRFOIL 1ST STAGE BLADE
ENGINEER BRANSTROM EXT 2824 DATE 6/24/87

AERODYNAMIC DESIGN POINT 109% Power - Des. Table 0387.8 dated 4/19/87

F.T.D. LIST:

ELEVATION _____

AIRFOIL SECTIONS _____

AIRFOIL COORDINATES _____

DF LIST:

GAGING VS. RADIUS _____

FLOW AREA VS. ROTATION _____

STRESS VS. % SPAN _____

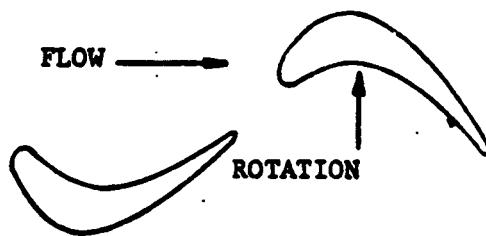
PRESSURE DIST. _____

BOUNDARY LAYER _____ N.A.

CHECK ONE

P&WA CONVENTIONAL ROTATION

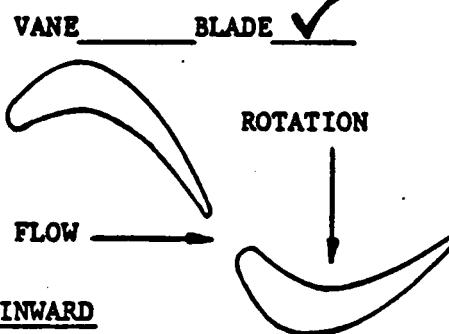
VANE _____ BLADE _____



P&WA COUNTER ROTATION ✓

VANE _____ BLADE ✓

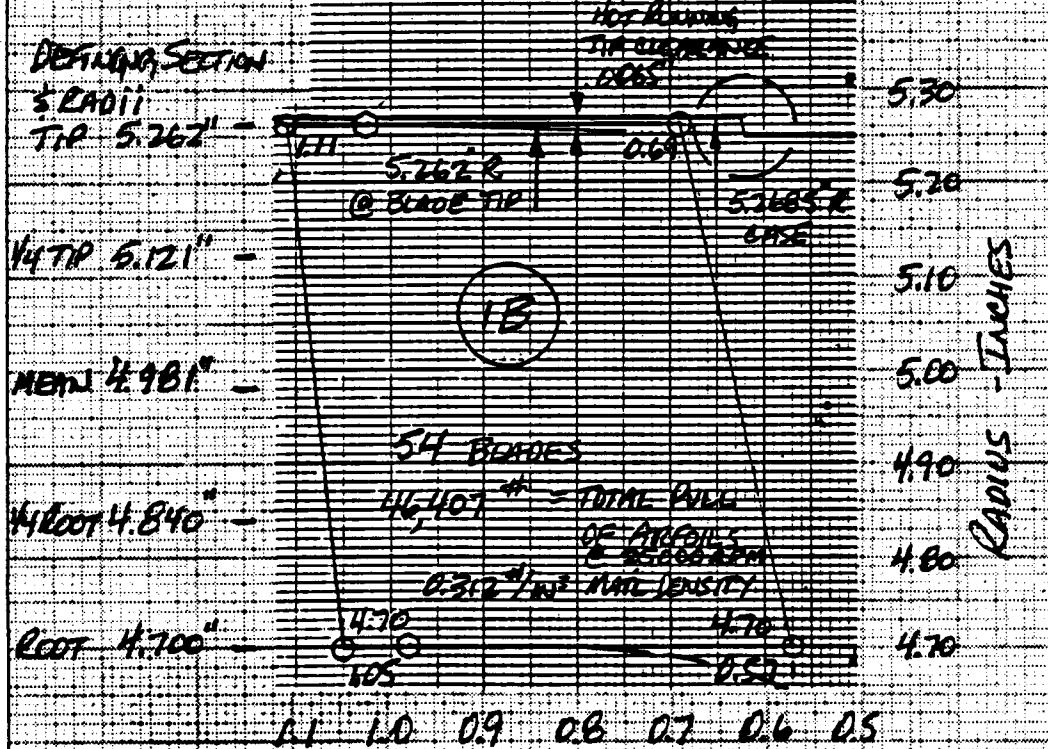
VIEW LOOKING RADIALLY INWARD



A.T.D. OXIDIZER PUMP TURBINE

1ST STAGE BLADE

AIRFOIL IS CURVE LINE FAIRED BETWEEN DEFINING SECTIONS
 OVERALL TURBINE ELEVATION IS AT FOOT OF FTOM
 ALL DIMENSIONS ARE INCHES

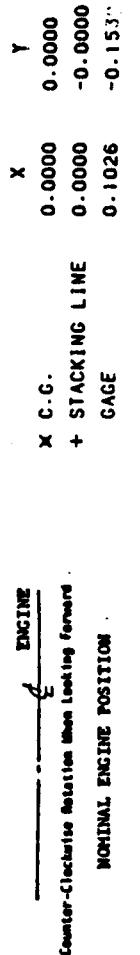
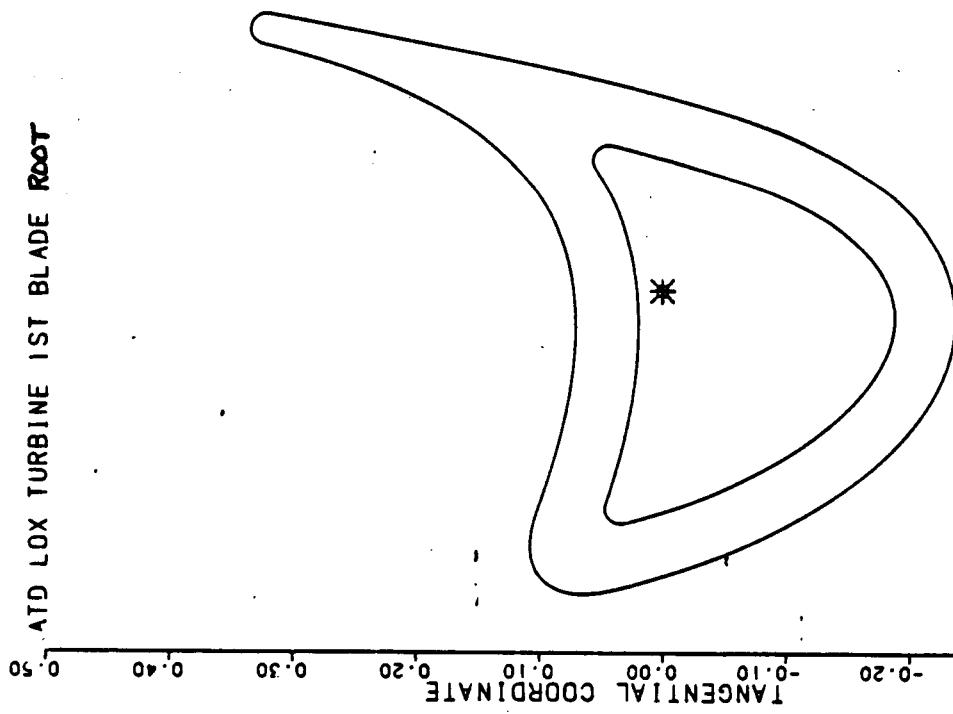


7/8/67
BB

ATD LOX TURBINE 1ST BLADE ROOT

CYLINDRICAL
SCALE 10.0
THERMAL SHRINK FACTOR 1.000000
08/17/87
11:51:33

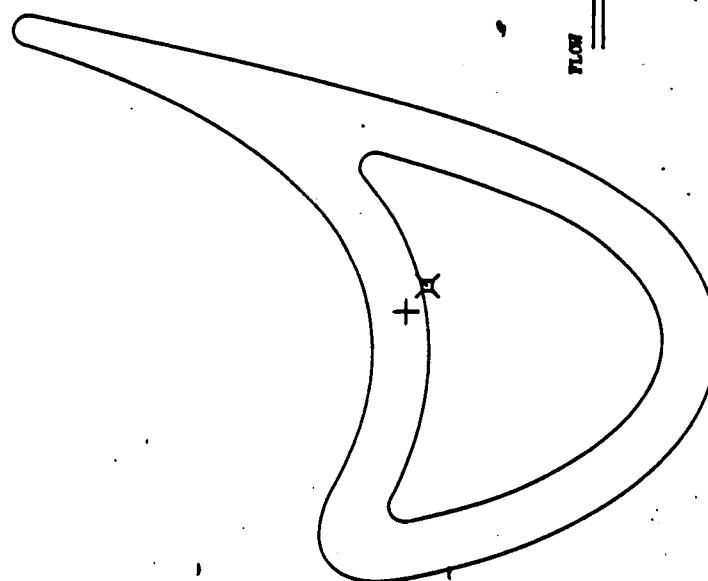
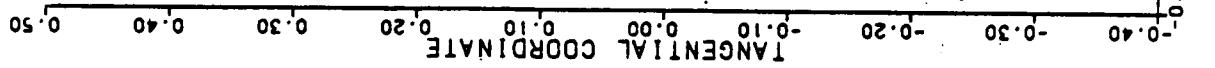
NUMBER OF BLADES	54.
RADIUS (HOT)	4.700 INCHES
GAGING (HOT)	0.1209 INCHES
PITCH (HOT)	0.5469 INCHES
AXIAL WIDTH	0.4794 INCHES
GAGE INLET ANGLE	42.0 DEGREES
GAS INLET ANGLE	27.68 DEGREES
BANG EXIT ANGLE	12.274 DEGREES
GAS EXIT ANGLE	12.274 DEGREES
GAGING ANGLE	12.775 DEGREES
UNCOVERED TURNING	21.636 DEGREES
LEADING EDGE RADIUS	0.0172 INCHES
TRAILING EDGE RADIUS	0.0125 INCHES
TOTAL AREA (SOLID)	0.1156 SQ. IN.
METAL AREA	0.0676 SQ. IN.
(NET, UNCOATED)	



A1D LOX TURBINE 1ST BLADE 1/4 Root

CYLINDRICAL
SCALE 10.0
THERMAL SHRINK FACTOR 1.000000
08/17/87
11:51:33

NUMBER OF BLADES	54.
RADIUS (HOT)	4.840 INCHES
GAGING (HOT)	0.1409 INCHES
PITCH (HOT)	0.5632 INCHES
AXIAL WIDTH	0.4644 INCHES
BLADE INLET ANGLE	26.0 DEGREES
GAS INLET ANGLE	22.45 DEGREES
BLADE EXIT ANGLE	14.315 DEGREES
GAS EXIT ANGLE	14.444 DEGREES
GAGING ANGLE	14.488 DEGREES
UNCOVERED TURNING	21.770 DEGREES
LEADING EDGE RADIUS	0.0218 INCHES
TRAILING EDGE RADIUS	0.0125 INCHES
TOTAL AREA (SOLID)	0.1045 SQ. IN.
METAL AREA (NET, UNCOATED)	0.0612 SQ. IN.



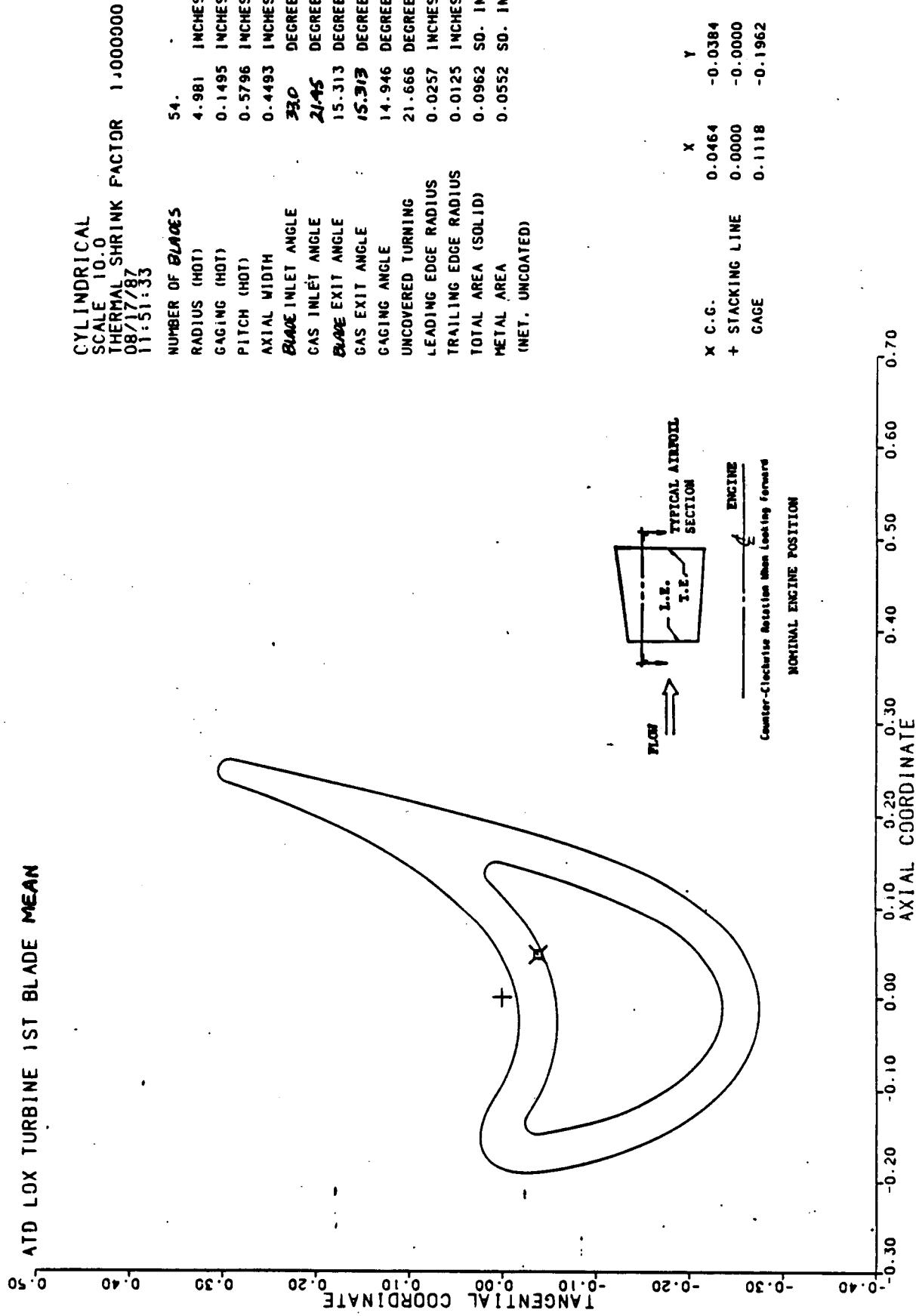
Center-Clockwise Rotation When Looking forward
NOMINAL ENGINE POSITION

X C.G. 0.0209 -0.0172
+ STACKING LINE 0.0000 -0.0000
GAGE 0.1031 -0.1707

A1D LOX TURBINE 1ST BLADE MEAN

CYLINDRICAL
SCALE 10.0
THERMAL SHRINK FACTOR 1.000000
08/17/87
11:51:33

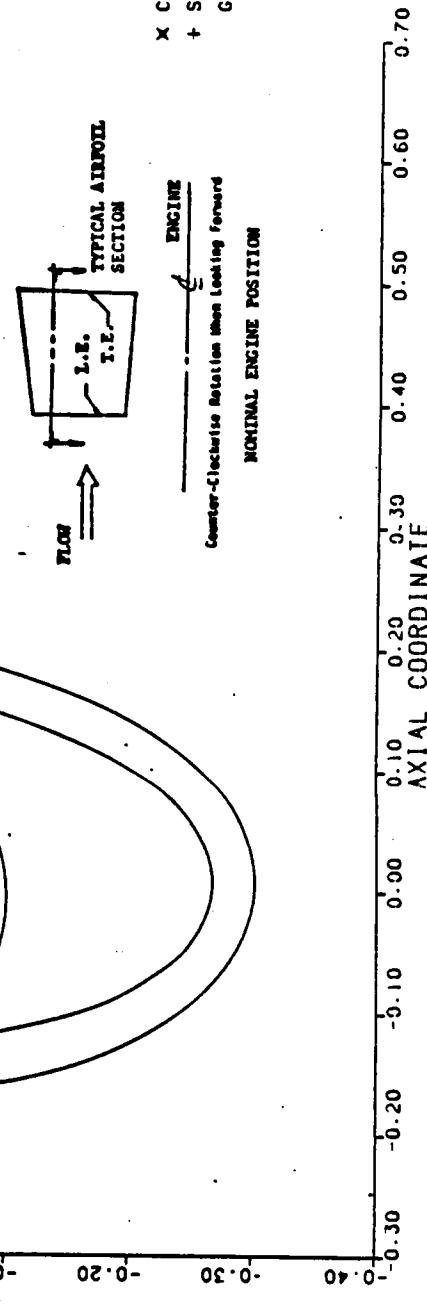
NUMBER OF BLADES	54.
RADIUS (HOT)	4.981 INCHES
GAGING (HOT)	0.1495 INCHES
PITCH (HOT)	0.5796 INCHES
AXIAL WIDTH	0.4493 INCHES
BLADE INLET ANGLE	33.0 DEGREES
GAS INLET ANGLE	27.45 DEGREES
BLADE EXIT ANGLE	15.313 DEGREES
GAS EXIT ANGLE	15.313 DEGREES
GAGING ANGLE	14.946 DEGREES
UNCOVERED TURNING	21.666 DEGREES
LEADING EDGE RADIUS	0.0257 INCHES
TRAILING EDGE RADIUS	0.0125 INCHES
TOTAL AREA (SOLID)	0.0962 SQ. IN.
METAL AREA	0.0552 SQ. IN.
(NET, UNCOATED)	



AID LOX TURBINE 1ST BLADE 1/4 TIP

CYLINDRICAL
SCALE 10.0
THERMAL SHRINK FACTOR 1.000000
08/17/87
11:51:33

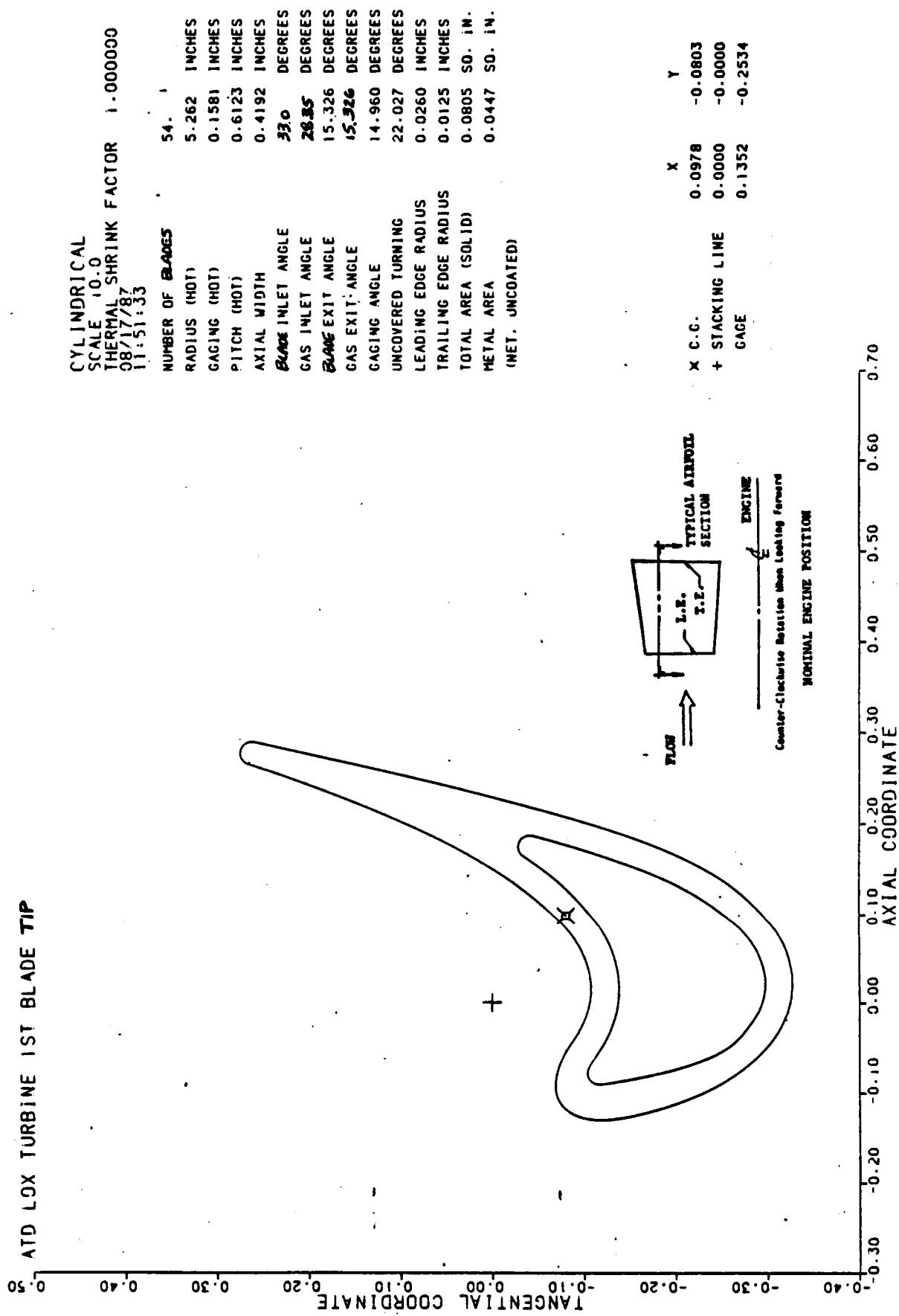
NUMBER OF BLADES	54.
RADIUS (HOT)	5.121 INCHES
GAGING (HOT)	0.1514 INCHES
PITCH (HOT)	0.5959 INCHES
AXIAL WIDTH	0.4342 INCHES
BLADE INLET ANGLE	33.0 DEGREES
GAS INLET ANGLE	22.62 DEGREES
BLADE EXIT ANGLE	15.391 DEGREES
GAS EXIT ANGLE	15.381 DEGREES
GAGING ANGLE	14.724 DEGREES
UNCOVERED TURNING	21.773 DEGREES
LEADING EDGE RADIUS	0.0262 INCHES
TRAILING EDGE RADIUS	0.0125 INCHES
TOTAL AREA (SOLID)	0.0883 SQ. IN.
METAL AREA	0.0503 SQ. IN.
(NET, UNCOATED)	



AIAI LOX TURBINE 1ST BLADE TIP

CYLINDRICAL
 SCALE 10.0
 THERMAL SHRINK FACTOR 1.000000
 08/17/87
 11:51:33

NUMBER OF BLADES	54.
RADIUS (HOT)	5.262 INCHES
GAGING (HOT)	0.1581 INCHES
PITCH (HOT)	0.6123 INCHES
AXIAL WIDTH	0.4192 INCHES
BLADE INLET ANGLE	33.0 DEGREES
GAS INLET ANGLE	28.35 DEGREES
BLADE EXIT ANGLE	15.326 DEGREES
GAS EXIT ANGLE	15.326 DEGREES
GAGING ANGLE	14.960 DEGREES
UNCOVERED TURNING	22.027 DEGREES
LEADING EDGE RADIUS	0.0260 INCHES
TRAILING EDGE RADIUS	0.0125 INCHES
TOTAL AREA (SOLID)	0.0805 SQ. IN.
METAL AREA (NET, UNCOATED)	0.0447 SQ. IN.



EXTERNAL CLINTOUR TITLE - SATP LOK TURBINE 1ST BLADE
 TD 1 TD REV. 1 PART NO. END NO.
 SUBTITLE HOT RADIUS = 4.70000

DATE 06/24/87 TIME 13:07:58 CYLINDRICAL
 COLD RADIUS = 0.0 THERMAL SHRINK FACTOR = 1.00000

PRETMIST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.25095	-0.06472	-0.06519	-0.25095	-0.06574	-0.06519
0.010	-0.24615	-0.03512		-0.24615	-0.06783	
0.020	-0.24136	-0.01731		-0.24136	-0.09510	
0.030	-0.23656	-0.00120		-0.23656	-0.09964	
0.040	-0.23177	0.01357		-0.23177	-0.10273	
0.050	-0.22697	0.02722		-0.22697	-0.10484	
0.060	-0.22210	0.03992		-0.22210	-0.10623	
0.070	-0.21739	0.05181		-0.21739	-0.10704	
0.080	-0.21259	0.06298		-0.21259	-0.10739	
0.090	-0.20780	0.07352		-0.20780	-0.10733	
0.100	-0.20300	0.08347		-0.20300	-0.10623	
0.125	-0.19102	0.10617		-0.19102	-0.10460	
0.150	-0.17903	0.12616		-0.17903	-0.10975	
0.175	-0.16705	0.14391		-0.16705	-0.09671	
0.200	-0.15506	0.15966		-0.15506	-0.09287	
0.225	-0.14308	0.17363		-0.14308	-0.08927	
0.250	-0.13109	0.18598		-0.13109	-0.08592	
0.275	-0.11910	0.19684		-0.11910	-0.08233	
0.300	-0.10712	0.20629		-0.10712	-0.08004	
0.325	-0.09513	0.21461		-0.09513	-0.07757	
0.350	-0.08315	0.22214		-0.08315	-0.07541	
0.375	-0.07116	0.22683		-0.07116	-0.07343	
0.400	-0.05910	0.23119		-0.05910	-0.07223	
0.425	-0.04719	0.23435		-0.04719	-0.07127	
0.450	-0.03520	0.23630		-0.03520	-0.07077	
0.475	-0.02322	0.23702		-0.02322	-0.07070	
0.500	-0.01123	0.23650		-0.01123	-0.07136	
0.525	0.00075	0.23471		0.00075	-0.07254	
0.550	0.01274	0.23158		0.01274	-0.07441	
0.575	0.02472	0.22707		0.02472	-0.07703	
0.600	0.03671	0.22107		0.03671	-0.08048	
0.625	0.04870	0.21347		0.04870	-0.08486	
0.650	0.06068	0.20412		0.06068	-0.09029	
0.675	0.07267	0.19282		0.07267	-0.09689	
0.700	0.08465	0.17928		0.08465	-0.10493	
0.725	0.09664	0.16313		0.09664	-0.11428	
0.750	0.10862	0.14377		0.10862	-0.12546	
0.775	0.12061	0.12042		0.12061	-0.13865	
0.800	0.13260	0.09219		0.13260	-0.15416	
0.825	0.14450	0.05832		0.14450	-0.17261	
0.850	0.15657	0.01841		0.15657	-0.19388	
0.875	0.16855	-0.02746		0.16855	-0.21921	
0.900	0.18054	-0.07674		0.18054	-0.24925	
0.910	0.18533	-0.10059		0.18533	-0.26282	
0.920	0.19013	-0.12311		0.19013	-0.27759	
0.930	0.19492	-0.14626		0.19492	-0.29207	
0.940	0.19972	-0.16997		0.19972	-0.30996	
0.950	0.20451	-0.19420		0.20451	-0.32819	-0.32755
0.960	0.20930	-0.21889		0.20930	-0.34791	-0.33315
0.970	0.21410	-0.24399		0.21410	-0.36928	-0.3494
0.980	0.21889	-0.26948		0.21889	-0.39249	-0.33674
0.990	0.22369	-0.29531		0.22369	-0.41778	-0.32243
1.000	0.22848	-0.32146	-0.32259	0.22848	-0.44562	-0.32259

NO. 1 CORE CONTOUR
TD 1 TD REV. 1 PART NO. END NO.
SUBTITLE COLD RADIUS = 4.70000

TITLE - SATP LOK TURBINE 1ST BLADE
DATE 06/24/87 TIME 13:07:58
CYLINDRICAL
COLD RADIUS = 0.0 THERMAL SHRINK FACTOR = 1.00000

PENTIST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.19308	-0.03371	-0.03535	-0.19308	-0.03287	-0.19355
0.010	-0.18994	-0.02228	-0.18994	-0.02173	-0.04364	
0.020	-0.18679	-0.01147	-0.18679	-0.00962	-0.04619	
0.030	-0.18365	-0.00126	-0.18365	-0.00953	-0.04746	
0.040	-0.18051	0.00833	-0.18051	-0.00847	-0.04784	
0.050	-0.17737	0.01731	-0.17737	-0.00743	-0.04742	
0.060	-0.17422	0.02569	-0.17422	-0.00644		
0.070	-0.17108	0.03352	-0.17108	-0.00546		
0.080	-0.16794	0.04081	-0.16794	-0.00451		
0.090	-0.16479	0.04782	-0.16479	-0.00356		
0.100	-0.16165	0.05443	-0.16165	-0.00263		
0.125	-0.15379	0.06966	-0.15379	-0.00035		
0.150	-0.14594	0.08417	-0.14594	-0.00114		
0.175	-0.13808	0.10735	-0.13808	-0.00605		
0.200	0.13022	0.10938	-0.13022	-0.03408		
0.225	-0.12237	0.12032	-0.12237	-0.02222		
0.250	-0.11451	0.13028	-0.11451	-0.02049		
0.275	-0.10665	0.13936	-0.10665	-0.02888		
0.300	-0.09880	0.14762	-0.09880	-0.02738		
0.325	-0.09094	0.15506	-0.09094	-0.02002		
0.350	-0.08308	0.16176	-0.08308	-0.01681		
0.375	-0.07523	0.16764	-0.07523	-0.02374		
0.400	-0.06737	0.17276	-0.06737	-0.02281		
0.425	-0.05951	0.17717	-0.05951	-0.02205		
0.450	-0.05165	0.18050	-0.05165	-0.02145		
0.475	-0.04380	0.18362	-0.04380	-0.02102		
0.500	-0.03594	0.18562	-0.03594	-0.02077		
0.525	-0.02808	0.18676	-0.02808	-0.02071		
0.550	-0.02023	0.18699	-0.02023	-0.02084		
0.575	-0.01237	0.18623	-0.01237	-0.02118		
0.600	-0.00451	0.18456	-0.00451	-0.02173		
0.625	0.00334	0.18183	0.00334	-0.02449		
0.650	0.01120	0.17804	0.01120	-0.02350		
0.675	0.01906	0.17316	0.01906	-0.02475		
0.700	0.02692	0.16720	0.02692	-0.02624		
0.725	0.03477	0.16006	0.03477	-0.02801		
0.750	0.04263	0.15169	0.04263	-0.03006		
0.775	0.05049	0.14176	0.05049	-0.03240		
0.800	0.05834	0.13039	0.05834	-0.03503		
0.825	0.06620	0.11720	0.06620	-0.03800		
0.850	0.07406	0.10189	0.07406	-0.04132		
0.875	0.08191	0.08425	0.08191	-0.04500		
0.900	0.08977	0.06400	0.08977	-0.04908		
0.910	0.09291	0.05513	0.09291	-0.05092		
0.920	0.09606	0.04580	0.09606	-0.05263		
0.930	0.09920	0.03601	0.09920	-0.05451		
0.940	0.10234	0.02579	0.10234	-0.05646		
0.950	0.10548	0.01514	0.10548	-0.05848		
0.960	0.10863	0.00409	0.10863	-0.06057		
0.970	0.11177	-0.00757	0.11177	-0.06275		
0.980	0.11491	-0.01922	0.11491	-0.06500		
0.990	0.11806	-0.03147	0.11806	-0.06754		
1.000	0.12120	-0.04412	0.04563	0.12120	-0.06977	-0.04563

EXTERNAL C.../OUR
TD SUBTITLE 1 TD REV. 1 PART NO. TITLE - SATP LOX TURBINE 1ST BLADE
END NO. HOT RADIUS = 4.040000 COLD RADIUS = 0.0

DATE 06/24/87 TIME 13:07:58 CYLINDRICAL
THERMAL SHRINK FACTOR = 1.000000

PRETWIST NOT USED FOR TD PRINTOUT.

PCT	X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.22096	-0.02263	-0.02316	-0.22096	-0.02377	-0.02316	
0.010	-0.21632	0.01052	-0.21632	-0.06803	-0.21632	-0.06803	
0.020	-0.21167	0.03064	-0.21167	-0.05603	-0.21167	-0.05603	
0.030	-0.20703	0.04796	-0.20703	-0.04105	-0.20703	-0.04105	
0.040	-0.20239	0.06328	-0.20239	-0.03446	-0.20239	-0.03446	
0.050	-0.19774	0.07707	-0.19774	-0.02681	-0.19774	-0.02681	
0.060	-0.19310	0.08966	-0.19310	-0.01835	-0.19310	-0.01835	
0.070	-0.18846	0.10123	-0.18846	-0.01927	-0.18846	-0.01927	L.E. CIRCLE (X,Y,R)
0.080	-0.18381	0.11193	-0.18381	-0.01966	-0.18381	-0.01966	T.E. CIRCLE (X,Y,R)
0.090	-0.17917	0.12189	-0.17917	-0.01961	-0.17917	-0.01961	L.E. TOP TANG. PT. (X,Y)
0.100	-0.17453	0.13119	-0.17453	-0.01918	-0.17453	-0.01918	L.E. BOTTOM TANG. PT. (X,Y)
0.125	-0.16292	0.15190	-0.16292	-0.01660	-0.16292	-0.01660	T.E. TOP TANG. PT. (X,Y)
0.150	-0.15131	0.16986	-0.15131	-0.01224	-0.15131	-0.01224	T.E. BOTTOM TANG. PT. (X,Y)
0.175	-0.13970	0.18532	-0.13970	-0.01638	-0.13970	-0.01638	T.E. BOTTOM TANG. PT. (X,Y)
0.200	-0.12809	0.19872	-0.12809	-0.01209	-0.12809	-0.01209	NOSE POINT (X,Y)
0.225	-0.11648	0.21029	-0.11648	-0.01148	-0.11648	-0.01148	TAIL POINT (X,Y)
0.250	-0.10487	0.22021	-0.10487	-0.01078	-0.10487	-0.01078	NET CROSS-SECT. AREA (EXCL. COATING)
0.275	-0.09326	0.22863	-0.09326	-0.01352	-0.09326	-0.01352	0.06118
0.300	-0.08165	0.23563	-0.08165	-0.01352	-0.08165	-0.01352	0.10306
0.325	-0.07004	0.24131	-0.07004	-0.01352	-0.07004	-0.01352	0.17073
0.350	-0.05843	0.24571	-0.05843	-0.01352	-0.05843	-0.01352	0.14082
0.375	-0.04682	0.24886	-0.04682	-0.01352	-0.04682	-0.01352	14.488
0.400	-0.03522	0.25083	-0.03522	-0.01352	-0.03522	-0.01352	
0.425	-0.02361	0.25158	-0.02361	-0.01352	-0.02361	-0.01352	CTR. OF GRAV. (INCL. COATING) (X,Y)
0.450	-0.01200	0.25113	-0.01200	-0.01352	-0.01200	-0.01352	0.02095
0.475	-0.00339	0.24947	-0.00339	-0.01352	-0.00339	-0.01352	0.01719
0.500	0.01122	0.24458	0.01122	-0.01352	0.01122	-0.01352	0.00002
0.525	0.02283	0.24260	0.02283	-0.01352	0.02283	-0.01352	
0.550	0.03444	0.23688	0.03444	-0.01352	0.03444	-0.01352	
0.575	0.04605	0.22996	0.04605	-0.01352	0.04605	-0.01352	
0.600	0.05766	0.22153	0.05766	-0.01352	0.05766	-0.01352	
0.625	0.06927	0.21146	0.06927	-0.01352	0.06927	-0.01352	
0.650	0.08088	0.19955	0.08088	-0.01352	0.08088	-0.01352	
0.675	0.09249	0.18537	0.09249	-0.01352	0.09249	-0.01352	
0.700	0.10409	0.16917	0.10409	-0.01352	0.10409	-0.01352	
0.725	0.11570	0.14906	0.11570	-0.01352	0.11570	-0.01352	
0.750	0.12731	0.12706	0.12731	-0.01352	0.12731	-0.01352	
0.775	0.13892	0.10027	0.13892	-0.01352	0.13892	-0.01352	
0.800	0.15053	0.06912	0.15053	-0.01352	0.15053	-0.01352	
0.825	0.16214	0.03553	0.16214	-0.01352	0.16214	-0.01352	
0.850	0.17275	-0.00629	0.17275	-0.01352	0.17275	-0.01352	
0.875	0.18336	-0.04993	0.18336	-0.01352	0.18336	-0.01352	
0.900	0.19497	-0.09481	0.19497	-0.01352	0.19497	-0.01352	
0.910	0.20161	-0.11634	0.20161	-0.01352	0.20161	-0.01352	
0.920	0.20625	-0.15227	0.20625	-0.01352	0.20625	-0.01352	
0.930	0.21090	-0.15535	0.21090	-0.01352	0.21090	-0.01352	
0.940	0.21554	-0.17717	0.21554	-0.01352	0.21554	-0.01352	
0.950	0.22019	-0.19809	0.22019	-0.01352	0.22019	-0.01352	
0.960	0.22483	-0.21929	0.22483	-0.01352	0.22483	-0.01352	
0.970	0.22967	-0.24076	0.22967	-0.01352	0.22967	-0.01352	
0.980	0.23412	-0.26241	0.23412	-0.01352	0.23412	-0.01352	
0.990	0.23876	-0.28630	0.23876	-0.01352	0.23876	-0.01352	
1.000	0.24240	-0.30258	0.24240	-0.01352	0.24240	-0.01352	

UNCOVERED TURNING ANGLE (DEG.)

21.770

AXIAL CHORD

0.46437

ACTUAL CHORD

0.54995

PITCH

0.56316

NO. OF FOILS

54

NO. 1 CORE CONTOUR
TD 1 TO REV. 1 PART NO. END NO.
SUBTITLE

TITLE - SATP LOK TURBINE 1ST BLADE
HOT RADIUS = 4.840000 COLD RADIUS = 0.0 THERMAL SHRINK FACTOR = 1.000000

PRETEST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.17191	-0.00044	-0.00183	-0.17191	-0.02209	-0.00183
0.010	-0.16887	0.01274		-0.16887	-0.02083	-0.01003
0.020	-0.16583	0.02514		-0.16583	-0.01944	-0.01259
0.030	-0.16279	0.03676		-0.16279	-0.01793	-0.01392
0.040	-0.15975	0.04759		-0.15975	-0.01632	-0.01439
0.050	-0.15671	0.05760		-0.15671	-0.01467	-0.01412
0.060	-0.15367	0.06679		-0.15367	-0.01304	-0.01304
0.070	-0.15062	0.07522		-0.15062	-0.01145	L.E. CIRCLE (X,Y,R)
0.080	-0.14758	0.08296		-0.14758	-0.00992	T.E. CIRCLE (X,Y,R)
0.090	-0.14454	0.09009		-0.14454	-0.00847	
0.100	-0.14150	0.09673		-0.14150	-0.00707	L.E. TOP TANG. PT. (X,Y)
0.125	-0.13390	0.11175		-0.13390	-0.00380	L.E. BOTTOM TANG. PT. (X,Y)
0.150	-0.12629	0.12538		-0.12629	-0.00079	T.E. TOP TANG. PT. (X,Y)
0.175	-0.11869	0.13774		-0.11869	0.00205	T.E. BOTTOM TANG. PT. (X,Y)
0.200	-0.11109	0.14877		-0.11109	0.00468	
0.225	-0.10348	0.15856		-0.10348	0.00710	NOSE POINT (X,Y)
0.250	-0.09588	0.16728		-0.09588	0.00927	TAIL POINT (X,Y)
0.275	-0.08827	0.17504		-0.08827	0.01121	
0.300	-0.08067	0.18189		-0.08067	0.01289	
0.325	-0.07307	0.18787		-0.07307	0.01433	
0.350	-0.06546	0.19301		-0.06546	0.01554	
0.375	-0.05786	0.19732		-0.05786	0.01649	
0.400	-0.05026	0.20082		-0.05026	0.01721	
0.425	-0.04265	0.20350		-0.04265	0.01766	
0.450	-0.03505	0.20537		-0.03505	0.01787	
0.475	-0.02745	0.20638		-0.02745	0.01780	
0.500	-0.01984	0.20656		-0.01984	0.01749	
0.525	-0.01224	0.20586		-0.01224	0.01689	
0.550	-0.00463	0.20430		-0.00463	0.01604	
0.575	0.00297	0.20187		0.00297	0.01490	
0.600	0.01057	0.19856		0.01057	0.01348	
0.625	0.01818	0.19436		0.01818	0.01178	
0.650	0.02578	0.18926		0.02578	0.00977	
0.675	0.03338	0.18322		0.03338	0.00746	
0.700	0.04099	0.17620		0.04099	0.00485	
0.725	0.04859	0.16814		0.04859	0.00191	
0.750	0.05619	0.15893		0.05619	-0.00136	
0.775	0.06380	0.14849		0.06380	-0.00497	
0.800	0.07140	0.13661		0.07140	-0.00892	
0.825	0.07901	0.12312		0.07901	-0.01325	
0.850	0.08661	0.10786		0.08661	-0.01796	
0.875	0.09421	0.09059		0.09421	-0.02304	
0.900	0.10182	0.07152		0.10182	-0.02853	
0.910	0.10486	0.06326		0.10486	-0.03085	
0.920	0.10790	0.05472		0.10790	-0.03325	
0.930	0.11094	0.04582		0.11094	-0.03571	
0.940	0.11398	0.03658		0.11398	-0.03825	0.03765
0.950	0.11702	0.02703		0.11702	-0.04087	-0.03894
0.960	0.12006	0.01719		0.12006	-0.04355	-0.03922
0.970	0.12311	0.00705		0.12311	-0.04631	-0.03876
-0.980	0.12615	-0.00337		0.12615	-0.04914	-0.03744
0.990	0.12919	-0.01405		0.12919	-0.05205	-0.03488
1.000	0.13223	-0.02501	-0.02670	0.13223	-0.05504	-0.02670

NO. 1 CORE - OUTOUR
TD 1 TD REV. 1 PART NO. TITLE - SATP LOK TURBINE 1ST BLADE
SUBTITLE END NO.
HOT RADIUS = 4.96100

DATE 06/24/87 TIME 13:07:58
COLD RADIUS = 0.0 THERMAL SHRINK FACTOR = 1.00000
CYLINDRICAL

PENT NOT USED FOR TO PRINTOUT.

PCT	X	Y	TOP	Y	TOP	(CIRCLE)	X	BOT	Y	BOT	(CIRCLE)
0.0	-0.14862	0.03734	0.03619	-0.14862	0.03614	0.03612					
0.010	-0.14564	0.05276		-0.14564	0.01781	0.02810					
0.020	-0.14267	0.06710		-0.14267	0.01906	0.02555					
0.030	-0.13969	0.08031		-0.13969	0.02040	0.02422					
0.040	-0.13672	0.09236		-0.13672	0.02181	0.02171					
0.050	-0.13374	0.10330		-0.13374	0.02230	0.02292					
0.060	-0.13077	0.11304		-0.13077	0.02248	0.02490					
0.070	-0.12779	0.12170		-0.12779	0.02262		L.E. CIRCLE (X,Y,R)		-0.12612	0.03619	0.01249
0.080	-0.12482	0.12939		-0.12482	0.02283		T.E. CIRCLE (X,Y,R)		0.13641	-0.00739	0.01258
0.090	-0.12184	0.13626		-0.12184	0.02297						
0.100	-0.11887	0.14245		-0.11887	0.02317		L.E. TOP TANG. PT. (X,Y)		-0.16840	0.03651	
0.125	-0.11143	0.15611		-0.11143	0.03007		L.E. BOTTOM TANG. PT. (X,Y)		-0.15012	0.02523	
0.150	-0.10399	0.16857		-0.10399	0.04008		T.E. TOP TANG. PT. (X,Y)		0.14843	-0.00407	
0.175	-0.09656	0.17991		-0.09656	0.04355		T.E. BOTTOM TANG. PT. (X,Y)		0.12744	-0.01607	
0.200	-0.08912	0.18989		-0.08912	0.04553						
0.225	-0.08168	0.19850		-0.08168	0.04910		NOSE POINT (X,Y)		-0.16347	0.02608	
0.250	-0.07424	0.20602		-0.07424	0.05133		TAIL POINT (X,Y)		0.14260	-0.01622	
0.275	-0.06681	0.21260		-0.06681	0.05326						
0.300	-0.05937	0.21829		-0.05937	0.05490						
0.325	-0.05193	0.22310		-0.05193	0.05622						
0.350	-0.04449	0.22707		-0.04449	0.05722						
0.375	-0.03706	0.23021		-0.03706	0.05708						
0.400	-0.02962	0.23256		-0.02962	0.05819						
0.425	-0.02218	0.23411		-0.02218	0.05817						
0.450	-0.01474	0.23485		-0.01474	0.05784						
0.475	-0.00731	0.23481		-0.00731	0.05718						
0.500	0.00013	0.23396		0.00013	0.05616						
0.525	0.00757	0.23233		0.00757	0.05487						
0.550	0.01501	0.22990		0.01501	0.05322						
0.575	0.02244	0.22668		0.02244	0.05124						
0.600	0.02988	0.22267		0.02988	0.04891						
0.625	0.03732	0.21784		0.03732	0.04624						
0.650	0.04476	0.21215		0.04476	0.04322						
0.675	0.05220	0.20553		0.05220	0.03985						
0.700	0.05963	0.19806		0.05963	0.03611						
0.725	0.06707	0.18953		0.06707	0.03202						
0.750	0.07451	0.17984		0.07451	0.02752						
0.775	0.08195	0.16889		0.08195	0.02267						
0.800	0.08938	0.15650		0.08938	0.01741						
0.825	0.09682	0.14251		0.09682	0.01174						
0.850	0.10426	0.12672		0.10426	0.00566						
0.875	0.11170	0.10912		0.11170	0.00085						
0.900	0.11913	0.08965		0.11913	-0.00779						
0.920	0.12211	0.06134		0.12211	-0.01069						
0.930	0.12806	0.03684		0.12806	-0.01667						
0.940	0.13103	0.05467		0.13103	-0.01665						
0.950	0.13401	0.04553		0.13401	-0.02304						
0.960	0.13698	0.03552		0.13698	-0.02631						
0.970	0.13996	0.02557		0.13996	-0.02966						
-0.980	0.14293	0.01538		0.14293	-0.03309						
0.990	0.14591	0.00495		0.14591	-0.03660						
1.000	0.14888	-0.00570		-0.00739	0.14888						

EXTERNAL CLUST4R
TD 1 TD REV. 1 PART NO. TITLE - SAIP LOX TURBINE 1ST BLADE
SUBTITLE EMD NO. COLD RADIUS = 5.12100 TIME 13:07:58
PRETHIST NOT USED FOR TD PRINTOUT.

DATE 06/24/87 TIME 13:07:58
CYLINDRICAL
THERMAL SHRINK FACTOR = 1.00000

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.16074	0.07497	0.07437	-0.16074	0.07370	0.07437
0.010	-0.15640	0.10806		-0.15640	0.06472	
0.020	-0.15206	0.12688		-0.15206	0.04634	
0.030	-0.14772	0.14257		-0.14772	0.03500	
0.040	-0.14338	0.15612		-0.14338	0.03131	
0.050	-0.13903	0.16826		-0.13903	0.02270	
0.060	-0.13469	0.17905		-0.13469	0.02950	
0.070	-0.13035	0.18905		-0.13035	0.02774	
0.080	-0.12601	0.19813		-0.12601	0.02511	
0.090	-0.12167	0.20651		-0.12167	0.02292	
0.100	-0.11732	0.21428		-0.11732	0.02133	
0.125	-0.10647	0.23142		-0.10647	0.02714	
0.150	-0.09561	0.24588		-0.09561	0.03294	
0.175	-0.08476	0.25814		-0.08476	0.03532	
0.200	-0.07390	0.26852		-0.07390	0.04111	
0.225	-0.06305	0.27724		-0.06305	0.04941	
0.250	-0.05219	0.28447		-0.05219	0.05917	
0.275	-0.04134	0.29033		-0.04134	0.05917	
0.300	-0.03048	0.29490		-0.03048	0.06224	
0.325	-0.01962	0.29826		-0.01962	0.06117	
0.350	-0.00877	0.30046		-0.00877	0.06196	
0.375	0.00209	0.30150		0.00209	0.06463	
0.400	0.01294	0.30142		0.01294	0.06317	
0.425	0.02380	0.30022		0.02380	0.06056	
0.450	0.03465	0.29788		0.03465	0.05881	
0.475	0.04551	0.29440		0.04551	0.05190	
0.500	0.05636	0.28972		0.05636	0.04985	
0.525	0.06722	0.28379		0.06722	0.04662	
0.550	0.07807	0.27654		0.07807	0.04320	
0.575	0.08893	0.26784		0.08893	0.04058	
0.600	0.09978	0.25761		0.09978	0.03974	
0.625	0.11064	0.24559		0.11064	0.03234	
0.650	0.12150	0.23154		0.12150	0.01659	
0.675	0.13235	0.21508		0.13235	-0.03034	
0.700	0.14321	0.19569		0.14321	-0.04311	
0.725	0.15406	0.17288		0.15406	-0.04364	
0.750	0.16492	0.14627		0.16492	-0.08216	
0.775	0.17577	0.11575		0.17577	-0.10257	
0.800	0.18663	0.08145		0.18663	-0.12427	
0.825	0.19748	0.04375		0.19748	-0.14751	
0.850	0.20834	0.00316		0.20834	-0.17339	
0.875	0.21919	-0.03980		0.21919	-0.19995	
0.900	0.23005	-0.08467		0.23005	-0.22210	
0.910	0.23439	-0.10306		0.23439	-0.2316	
0.920	0.23873	-0.12167		0.23873	-0.25132	
0.930	0.24308	-0.14047		0.24308	-0.26380	
0.940	0.24742	-0.15946		0.24742	-0.27660	
0.950	0.25176	-0.17861		0.25176	-0.28773	-0.28619
0.960	0.25610	-0.19791		0.25610	-0.30320	-0.28925
0.970	0.26044	-0.21736		0.26044	-0.31000	-0.29023
0.980	0.26479	-0.23692		0.26479	-0.33116	-0.28964
0.990	0.26913	-0.25659		0.26913	-0.34570	-0.28721
1.000	0.27347	-0.27639	-0.27774	0.27347	-0.36060	-0.27774

NO. 1 CORE CONTOUR
TD 1 TD REV. 1 PART NO. END NO.
SUBTITLE HOT RADIUS = 5.12100 COLD RADIUS = 0.0 THERMAL SHRINK FACTOR = 1.00000

TITLE - SATP LOK TURBINE 1ST BLADE
PRETEST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.11264	0.07933	0.07852	-0.11264	0.05846	0.07852
0.010	-0.11676	0.09405		-0.11676	0.05976	0.07050
0.020	-0.11369	0.10746		-0.11369	0.06106	0.06793
0.030	-0.11102	0.11946		-0.11102	0.06237	0.06654
0.040	-0.10815	0.13154		-0.10815	0.06369	0.06594
0.050	-0.10528	0.14219		-0.10528	0.06510	0.06601
0.060	-0.10241	0.15190		-0.10241	0.06662	0.06676
0.070	-0.09953	0.16070		-0.09953	0.06826	0.06852
0.080	-0.09666	0.16868		-0.09666	0.07000	0.07263
0.090	-0.09379	0.17590		-0.09379	0.07181	
0.100	-0.09092	0.18247		-0.09092	0.07365	L.E. CIRCLE (X,Y,R)
0.125	-0.08374	0.19667		-0.08374	0.07813	L.E. CIRCLE (X,Y,R)
0.150	-0.07656	0.20870		-0.07656	0.08212	T.E. CIRCLE (X,Y,R)
0.175	-0.06938	0.21942		-0.06938	0.08562	T.E. CIRCLE (X,Y,R)
0.200	-0.06220	0.22946		-0.06220	0.08873	
0.225	-0.05502	0.23822		-0.05502	0.09147	NOSE POINT (X,Y)
0.250	-0.04784	0.24506		-0.04784	0.09383	TAIL POINT (X,Y)
0.275	-0.04066	0.25033		-0.04066	0.09579	
0.300	-0.03348	0.25480		-0.03348	0.09738	
0.325	-0.02631	0.25869		-0.02631	0.09859	
0.350	-0.01913	0.26180		-0.01913	0.09962	
0.375	-0.01195	0.26410		-0.01195	0.09988	
0.400	-0.00477	0.26565		-0.00477	0.09997	
0.425	0.00241	0.26647		0.00241	0.09970	
0.450	0.00959	0.26655		0.00959	0.09905	
0.475	0.01677	0.26588		0.01677	0.09803	
0.500	0.02395	0.26449		0.02395	0.09663	
0.525	0.03113	0.26239		0.03113	0.09486	
0.550	0.03831	0.25954		0.03831	0.09270	
0.575	0.04549	0.25594		0.04549	0.09015	
0.600	0.05267	0.25159		0.05267	0.08721	
0.625	0.05984	0.24646		0.05984	0.08586	
0.650	0.06702	0.24051		0.06702	0.08011	
0.675	0.07420	0.23369		0.07420	0.07595	
0.700	0.08138	0.22595		0.08138	0.07138	
0.725	0.08856	0.21720		0.08856	0.06637	
0.750	0.09574	0.20730		0.09574	0.06093	
0.775	0.10292	0.19610		0.10292	0.05503	
0.800	0.111010	0.18345		0.111010	0.04868	
0.825	0.11728	0.16918		0.11728	0.04187	
0.850	0.12446	0.15313		0.12446	0.03457	
0.875	0.13164	0.13529		0.13164	0.02681	
0.900	0.13882	0.11564		0.13882	0.01854	
0.910	0.14169	0.10730		0.14169	0.01510	
0.920	0.14456	0.09867		0.14456	0.01158	
0.930	0.14743	0.08976		0.14743	0.00796	0.00869
0.940	0.15030	0.08059		0.15030	0.00426	0.00711
0.950	0.15317	0.07115		0.15317	0.00048	0.00636
0.960	0.15605	0.06148		0.15605	-0.00338	0.00630
0.970	0.15892	0.05157		0.15892	-0.00733	0.00690
0.980	0.16179	0.04145		0.16179	-0.01136	0.00829
0.990	0.16466	0.03111		0.16466	0.01548	0.01086
1.000	0.16753	0.02055	0.01888	0.16753	-0.01968	0.01888

EXTERNAL 1-FOUR
TD 1 TD REV. 1 PART NO. TITLE - SAINT LOX TURBINE 1ST BLADE
SUBTITLE END NO. COLD RADIUS = 5.26200

DATE 06/24/87 TIME 13:07:58 CYLINDRICAL
THERMAL SHRINK FACTOR = 1.00000

PRENTIST NOT USED FOR TO PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.13054	0.11890	0.11832	-0.12054	0.11766	0.11832
0.010	-0.12634	0.15072		-0.12634	0.09306	
0.020	-0.12215	0.16825		-0.12215	0.08475	
0.030	-0.11796	0.18304		-0.11796	0.07943	
0.040	-0.11377	0.19593		-0.11377	0.07570	
0.050	-0.10958	0.20739		-0.10958	0.07304	
0.060	-0.10539	0.21771		-0.10539	0.07118	
0.070	-0.10120	0.22711		-0.10120	0.06992	
0.080	-0.09700	0.23572		-0.09700	0.06919	
0.090	-0.09281	0.24364		-0.09281	0.06889	
0.100	-0.08862	0.25097		-0.08862	0.06897	
0.125	-0.07614	0.26766		-0.07614	0.07060	
0.150	-0.06766	0.28051		-0.06766	0.07397	
0.175	-0.05718	0.29177		-0.05718	0.07694	
0.200	-0.04671	0.30117		-0.04671	0.08506	
0.225	-0.03623	0.30691		-0.03623	0.09197	
0.250	-0.02575	0.31515		-0.02575	0.09774	
0.275	-0.01527	0.32022		-0.01527	0.10218	
0.300	-0.00479	0.32359		-0.00479	0.10536	
0.325	0.00569	0.32594		0.00569	0.10715	
0.350	0.01617	0.32709		0.01617	0.10766	
0.375	0.02665	0.32710		0.02665	0.10687	
0.400	0.03712	0.32595		0.03712	0.10479	
0.425	0.04760	0.32364		0.04760	0.10137	
0.450	0.05808	0.32021		0.05808	0.09662	
0.475	0.06856	0.31556		0.06856	0.09055	
0.500	0.07904	0.30971		0.07904	0.08514	
0.525	0.08952	0.30256		0.08952	0.07444	
0.550	0.10000	0.29404		0.10000	0.06441	
0.575	0.11048	0.28402		0.11048	0.05310	
0.600	0.12095	0.27235		0.12095	0.04040	
0.625	0.13143	0.25983		0.13143	0.02640	
0.650	0.14191	0.24315		0.14191	0.01107	
0.675	0.15239	0.22489		0.15239	-0.00560	
0.700	0.16287	0.20372		0.16287	-0.02357	
0.725	0.17335	0.17930		0.17335	-0.04287	
0.750	0.18383	0.15149		0.18383	-0.06352	
0.775	0.19431	0.12029		0.19431	-0.08552	
0.800	0.20478	0.08593		0.20478	-0.10886	
0.825	0.21526	0.04871		0.21526	-0.13351	
0.850	0.22574	0.00904		0.22574	-0.15954	
0.875	0.23622	-0.03269		0.23622	-0.18689	
0.900	0.24670	-0.07612		0.24670	-0.21558	
0.910	0.25089	-0.09369		0.25089	-0.22743	
0.920	0.25508	-0.11107		0.25508	-0.23950	
0.930	0.25927	-0.13004		0.25927	-0.25179	
0.940	0.26347	-0.14838		0.26347	-0.26429	
0.950	0.26766	-0.16688		0.26766	-0.27699	-0.27192
0.960	0.27185	-0.18553		0.27185	-0.28992	-0.27447
0.970	0.27604	-0.20431		0.27604	-0.30310	-0.27522
0.980	0.28023	-0.22322		0.28023	-0.31648	-0.27452
0.990	0.28442	-0.24224		0.28442	-0.33005	-0.27206
1.000	0.28861	-0.26137		0.28861	-0.34383	-0.26272

NO. 1 CORE CONTOUR
TD 1 TD REV. 1 PART NO. END NO.
SUBTITLE

TITLE - SATP L05 TURBINE 1ST BLADE
DATE 06/24/87 TIME 13:07:58
COLD RADIUS = 5.26200 THERMAL SHRINK FACTOR = 1.00000

PRETEST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.09074	0.11676	0.11579	-0.02074	0.02708	0.11579
0.010	-0.08797	0.13395		-0.08797	0.09819	0.10795
0.020	-0.08521	0.14971		-0.08521	0.09929	0.10541
0.030	-0.08244	0.16402		-0.08244	0.10037	0.10402
0.040	-0.07967	0.17694		-0.07967	0.10146	0.10337
0.050	-0.07690	0.18853		-0.07690	0.10261	0.10336
0.060	-0.07413	0.19988		-0.07413	0.10388	0.10398
0.070	-0.07136	0.20821		-0.07136	0.10527	L.E. CIRCLE (X,Y,R)
0.080	-0.06860	0.21666		-0.06860	0.10681	T.E. CIRCLE (X,Y,R)
0.090	-0.06583	0.22434		-0.06583	0.10848	L.E. TOP TANG. PT. (X,Y)
0.100	-0.06306	0.23132		-0.06306	0.11025	L.E. BOTTOM TANG. PT. (X,Y)
0.125	-0.05614	0.24592		-0.05614	0.11483	T.E. TOP TANG. PT. (X,Y)
0.150	-0.04922	0.25693		-0.04922	0.11913	T.E. BOTTOM TANG. PT. (X,Y)
0.175	-0.04230	0.26516		-0.04230	0.12297	NOSE POINT (X,Y)
0.200	-0.03538	0.27162		-0.03538	0.12635	TAIL POINT (X,Y)
0.225	-0.02845	0.27716		-0.02845	0.12929	
0.250	-0.02153	0.28232		-0.02153	0.13177	
0.275	-0.01461	0.28689		-0.01461	0.13381	
0.300	-0.00769	0.29064		-0.00769	0.13541	
0.325	-0.00077	0.29346		-0.00077	0.13658	
0.350	0.00615	0.29544		0.00615	0.13753	
0.375	0.01307	0.29669		0.01307	0.13766	
0.400	0.01999	0.29723		0.01999	0.13757	
0.425	0.02691	0.29701		0.02691	0.13706	
0.450	0.03383	0.29607		0.03383	0.13613	
0.475	0.04075	0.29443		0.04075	0.13478	
0.500	0.04767	0.29207		0.04767	0.13299	
0.525	0.05459	0.28902		0.05459	0.13077	
0.550	0.06152	0.28526		0.06152	0.12810	
0.575	0.06844	0.28079		0.06844	0.12498	
0.600	0.07536	0.27558		0.07536	0.12140	
0.625	0.08228	0.26933		0.08228	0.11737	
0.650	0.08920	0.26286		0.08920	0.11284	
0.675	0.09612	0.25527		0.09612	0.10784	
0.700	0.10304	0.24674		0.10304	0.10236	
0.725	0.10996	0.23722		0.10996	0.09640	
0.750	0.11686	0.22657		0.11686	0.08993	
0.775	0.12380	0.21468		0.12380	0.08297	
0.800	0.13072	0.20142		0.13072	0.07548	
0.825	0.13764	0.18677		0.13764	0.06766	
0.850	0.14456	0.17045		0.14456	0.05890	
0.875	0.15149	0.15264		0.15149	0.04983	
0.900	0.15841	0.13329		0.15841	0.04022	
0.910	0.16117	0.12512		0.16117	0.03623	
0.920	0.16394	0.11672		0.16394	0.03222	
0.930	0.16671	0.10808		0.16671	0.02796	
0.940	0.16948	0.09920		0.16948	0.02369	
0.950	0.17225	0.09011		0.17225	0.01933	
0.960	0.17502	0.08081		0.17502	0.01489	
0.970	0.17778	0.07132		0.17778	0.01037	
-0.980	0.18055	0.06162		0.18055	0.00577	
0.990	0.18332	0.05174		0.18332	0.00108	
1.000	0.18609	0.04166	0.03999	0.18609	-0.00370	0.03999

P624 STACKING (OPTION 4) 1ST BLADE

CURRENT STACKING

CG ROOT SECTION	X	=	0.0000	Y	=	-0.0000
RAD REF (TYPE 1)	RRX	=	0.0	RRY	=	0.0000
STACKING OPTION	KOPX	=	1	KOPY	=	1
TILT	XTILT	=	0.1200	YTILT	=	0.0600
RESTAGGER	DEGREES	=	-0.1270	RADIANS	=	-0.002230

TABLE 1

SECTION

SEC	RADIUS	XOFFO	YOFFO	XOFF	YOFF	TOTAL	SECTION
1	4.7000	-0.2508	-0.3221	-0.2508	-0.3221	0.0	
2	4.8400	-0.2508	-0.3221	-0.2209	-0.3072	0.0	
3	4.9810	-0.2508	-0.3221	-0.1908	-0.2921	0.0	
4	5.1210	-0.2508	-0.3221	-0.1609	-0.2771	0.0	
5	5.2620	-0.2508	-0.3221	-0.1308	-0.2621	0.0	

TABLE 2

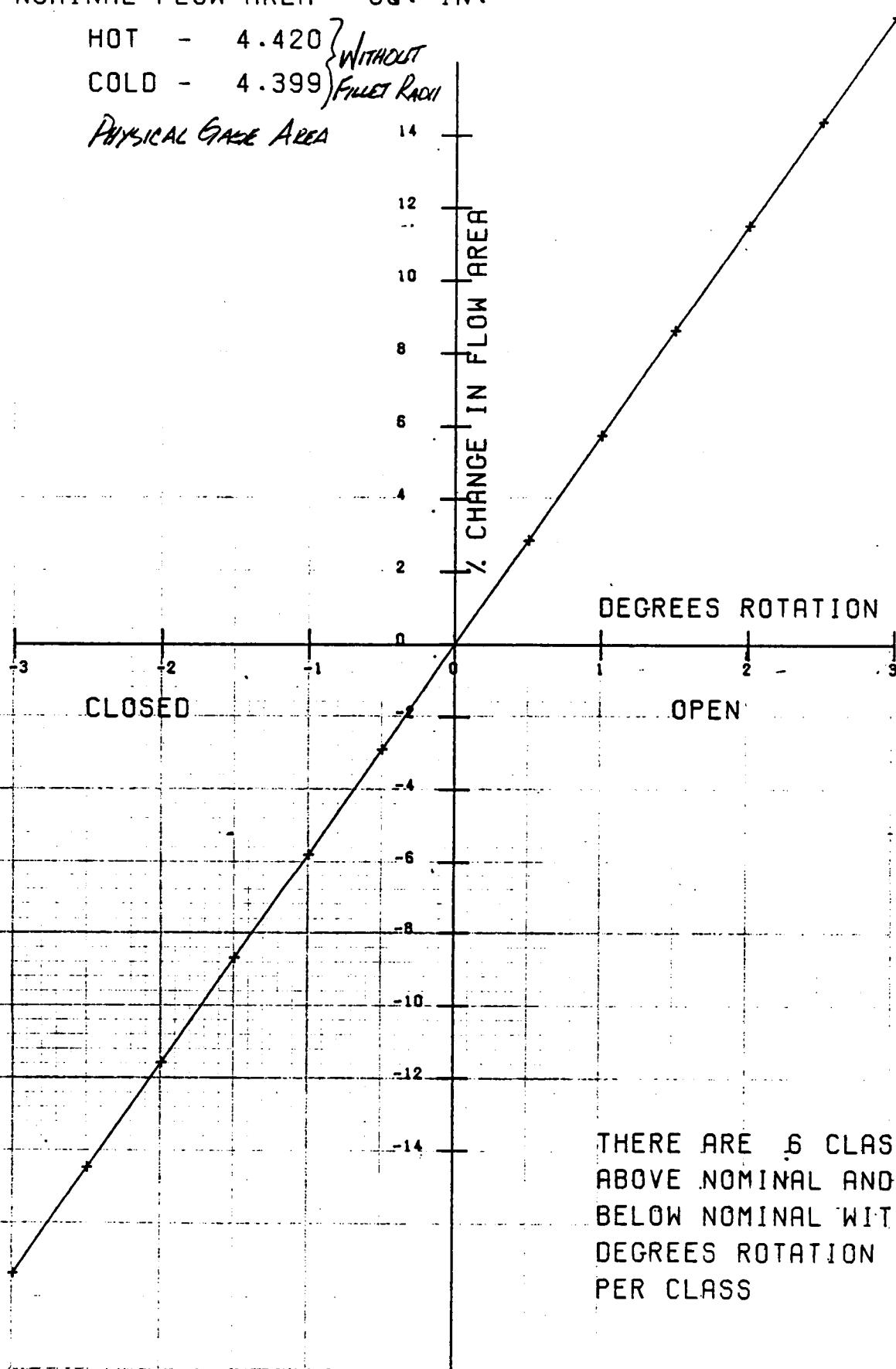
SECTION

SATP LOX TURBINE 1ST BLADE

NOMINAL FLOW AREA - SQ. IN.

HOT - 4.420 }
COLD - 4.399 } WITHOUT
{ FILLET RADIUS

PHYSICAL GAGE AREA



THERE ARE 6 CLASSES
ABOVE NOMINAL AND 6
BELOW NOMINAL WITH 0.50
DEGREES ROTATION
PER CLASS

DF117435

P824 UTILITY PROGRAM - FLOW AREA CALCULATION

SATP LOK TURBINE 1ST BLADE
HOT TO COLD CONVERSION RADII

HOT	COLD
4.70000	4.69000
4.84000	4.82000
4.98100	4.99000
5.12100	5.10800
5.26200	5.24700

RESTAGGER ANGLE DEGREES = -0.12777 RADIANS = -0.00223

PLATFORM RADII LE ID = 0.0 LE OD = 0.0

TE ID = 0.0 TE OD = 0.0

GAGING RADII INNER = 4.70000 OUTER = 5.26200

NUMBER OF VANES FOR GAGING = 54

STAGGER IN DEGREES IS -3.00 TO 3.00 IN INCREMENTS OF 0.50

IN CLASS IS -6 TO 6

TOLER = 0.0

STAGGER (DEGREES)	HOT FLOW (150 IN)	CHANGE FLOW AREA (150 IN)	COLD FLOW (150 IN)
-3.00000	3.65157	-17.35041	
-2.50000	3.78006	-16.48415	
-2.00000	3.90842	-11.58022	
-1.50000	4.03665	-8.67933	
-1.00000	4.16470	-5.78260	
-0.50000	4.29259	-2.88937	
0.0	4.42030	0.0	4.54939
0.50000	4.54783	2.88495	
1.00000	4.67515	5.75536	
1.50000	4.80248	8.62135	
2.00000	4.92981	11.51288	
2.50000	5.05591	14.37925	
3.00000	5.18238	17.24028	

— PHYSICAL GAGE AREA Without FILLET RADIUS

P824 UTILITY PROGRAM - STRESS CALCULATION

SATP LOX TURBINE 1ST BLADE	
ENGINE OPERATING CONDITION	
NAME	RPM
SATP LOX TURBINE 1ST BLADE	64.6 25000.
XGBM = 30.39999 XGBT = 7.60000 XGAT = 0.0	
YGBR = 32.42999 YGBT = 8.10000 YGAT = 0.0	
DENSITY = 0.31200 WEIGHTING RADIU INNER = 4.7000 OUTER = 5.2620	
SHROUD VOLUME = 0.0 SHROUD THICKNESS = 0.0	
SHROUD MISALIGNMENT = 0.0 RADIUS OF SHROUD = 0.0	

SATP LOX TURBINE 1ST BLADE			SATP LOX TURBINE 1ST BLADE		
OPERATING CONDITION 1			OPERATING CONDITION 2		
MAE = 64.6	HXR = 30.4	POH = 32.4	HXT = 8.1	HWT = 0.0	NET BENDING
RPM = 25000.	HXR =	POH =	HXT =	HWT =	CONV
0	4.7000	12715.	0.	-1288.	559.
10	4.7562	11726.	0.	-1588.	162.
20	4.8124	10690.	0.	-1676.	-114.
30	4.8686	9601.	0.	-1555.	-259.
40	4.9248	8650.	0.	-1276.	-317.
50	4.9810	7222.	0.	-907.	-270.
60	5.0372	5911.	0.	-548.	-144.
70	5.0934	4532.	0.	-265.	-23.
80	5.1496	3095.	0.	-92.	28.
90	5.2058	1588.	0.	-15.	19.
100	5.2620	0.	0.	0.	12.
					0.
%S	RADIUS	SIG P/A	SHRD P/A	LE	TE
%S	RADIUS	XOFF	YOFF	LE	TE
0	4.7000	0.0	0.0	12564.	5840.
10	4.7562	0.0078	0.0063	11160.	5296.
20	4.8124	0.0164	0.0135	9640.	4637.
30	4.8686	0.0258	0.0213	8050.	3914.
40	4.9248	0.0360	0.0296	6461.	3176.
50	4.9810	0.0464	0.0385	4833.	2417.
60	5.0372	0.0567	0.0479	3316.	1700.
70	5.0934	0.0669	0.0574	1993.	1049.
80	5.1496	0.0771	0.0662	949.	511.
90	5.2058	0.0874	0.0738	256.	140.
100	5.2620	0.0978	0.0803	0.	0.
					0.
%S	RADIUS	AREA	PBL	LE	TE
%S	RADIUS	POH	HXT	LE	TE
0	4.7000	0.0676	97.5	0.	0.
10	4.7562	0.0650	94.8	0.	0.
20	4.8124	0.0624	92.1	0.	0.
30	4.8686	0.0599	89.4	0.	0.
40	4.9248	0.0575	86.8	0.	0.
50	4.9810	0.0552	84.5	0.	0.
60	5.0372	0.0532	82.3	0.	0.
70	5.0934	0.0512	80.0	0.	0.
80	5.1496	0.0492	77.5	0.	0.
90	5.2058	0.0471	74.7	0.	0.
100	5.2620	0.0447	0.0	0.	0.
					0.
%S	RADIUS	HXT	HWT	HOC	THETA H
0	4.7000	-29.8	-38.3	30.4	32.4
10	4.7562	-25.3	-31.9	26.6	26.3
20	4.8124	-20.7	-25.8	19.5	20.8
30	4.8686	-16.3	-20.0	14.9	15.9
40	4.9248	-12.2	-16.6	10.9	11.7
50	4.9810	-8.5	-10.0	7.6	8.1
60	5.0372	-5.3	-6.3	4.9	5.2
70	5.0934	-2.8	-3.5	2.7	2.9
80	5.1496	-1.1	-1.5	1.2	1.3
90	5.2058	-0.2	-0.4	0.3	0.3
100	5.2620	0.0	0.0	0.0	0.0

SATP LOX TURBINE 1ST BLADE
 DENSITY = 0.31200 WEIGHTING RADIX INNER = 4.7000 OUTER = 5.2620
 SHROUD VOLUME = 0.0 SHROUD THICKNESS = 0.0
 SHROUD MISALIGNMENT = 0.0 RADIUS OF SHROUD = 0.0
 WEIGHT OF AIRFOIL = 0.00977 HEIGHT OF SHROUD = 0.0
 TOTAL WEIGHT = 0.52734 NUMBER OF BLADES = 54

SUMMARY OF SECTION PROPERTIES

Z/S	RADIUS	AREA	I MIN	I MAX	THETA	X BAR	Y BAR
0	4.7000	0.0676	0.7842E-03	0.1680E-02	-38.83	0.0000	0.0000
10	4.7562	0.0650	0.6905E-03	0.1650E-02	-40.35	0.0079	0.0063
20	4.8124	0.0624	0.6111E-03	0.1621E-02	-41.97	0.0164	0.0135
30	4.8686	0.0599	0.5426E-03	0.1594E-02	-43.63	0.0259	0.0213
40	4.9248	0.0575	0.4811E-03	0.1576E-02	-45.23	0.0360	0.0296
50	4.9810	0.0552	0.4326E-03	0.1554E-02	-46.70	0.0464	0.0385
60	5.0372	0.0532	0.3907E-03	0.1535E-02	-47.97	0.0568	0.0480
70	5.0934	0.0512	0.3533E-03	0.1516E-02	-49.11	0.0670	0.0574
80	5.1496	0.0492	0.3192E-03	0.1492E-02	-50.20	0.0771	0.0662
90	5.2058	0.0471	0.2854E-03	0.1463E-02	-51.26	0.0874	0.0759
100	5.2620	0.0447	0.2531E-03	0.1425E-02	-52.31	0.0976	0.0864
Z/S	RADIUS	K	L	MAX T	AX. WIDTH	C1	C2
0	4.7000	0.0	0.3937E-04	0.2367	0.4794	0.2146	0.1284
10	4.7562	0.0	0.5888E-04	0.2413	0.4734	0.2089	0.1200
20	4.8124	0.0	0.3861E-04	0.2477	0.4673	0.2035	0.1120
30	4.8686	0.0	0.3851E-04	0.2555	0.4613	0.1993	0.1048
40	4.9248	0.0	0.3849E-04	0.2647	0.4553	0.1932	0.0988
50	4.9810	0.0	0.3847E-04	0.2746	0.4493	0.1882	0.0944
60	5.0372	0.0	0.3832E-04	0.2854	0.4432	0.1831	0.0915
70	5.0934	0.0	0.3804E-04	0.2962	0.4372	0.1780	0.0894
80	5.1496	0.0	0.3762E-04	0.3068	0.4311	0.1729	0.0872
90	5.2058	0.0	0.3706E-04	0.3169	0.4251	0.1679	0.0844
100	5.2620	0.0	0.3638E-04	0.3271	0.4192	0.1629	0.0811
Z/S	RADIUS	C3	C4F	CTE	C4	ALPHA B	B
0	4.7000	0.1970	0.1412	0.3705	0.0807	62.66	0.5145
10	4.7562	0.1877	0.1376	0.3722	0.0950	61.64	0.5113
20	4.8124	0.1792	0.1349	0.3740	0.0956	60.45	0.5093
30	4.8686	0.1715	0.1337	0.3755	0.0977	59.10	0.5067
40	4.9248	0.1647	0.1342	0.3767	0.1011	57.58	0.5046
50	4.9810	0.1590	0.1360	0.3779	0.1051	55.97	0.5122
60	5.0372	0.1545	0.1385	0.3793	0.1093	54.34	0.5155
70	5.0934	0.1505	0.1416	0.3807	0.1132	52.72	0.5192
80	5.1496	0.1462	0.1451	0.3815	0.1165	51.19	0.5228
90	5.2058	0.1413	0.1491	0.3815	0.1190	49.77	0.5263
100	5.2620	0.1357	0.1537	0.3805	0.1206	48.61	0.5241

SATP LOX TURBINE 1ST BLADE

STRESS VS. SPAN AT 10% POWER

WRF = 54.8
 RPM = 25000.
 PULL = 880.
 DENS = 0.31200

1 SIC PYR SHROUD
 2 SIC PYR FOIL SHROUD
 3 SIC PYR + SIG SHMIS
 4 SIC PYR + SIG SHMIS + SIG 08
 5 SIC PYR + SIG SHMIS + SIG 08

30

CONDITION:
 SATP LOX TURBINE 1S
 BLADE

STRESS

STRESS
 (KSI)

✓ SPAN BASED ON
 WEIGHT RADI
 $R(100) = 4.7000$
 $R(000) = 5.2620$

10

0

0

10

20

30

40

50

60

70

80

90

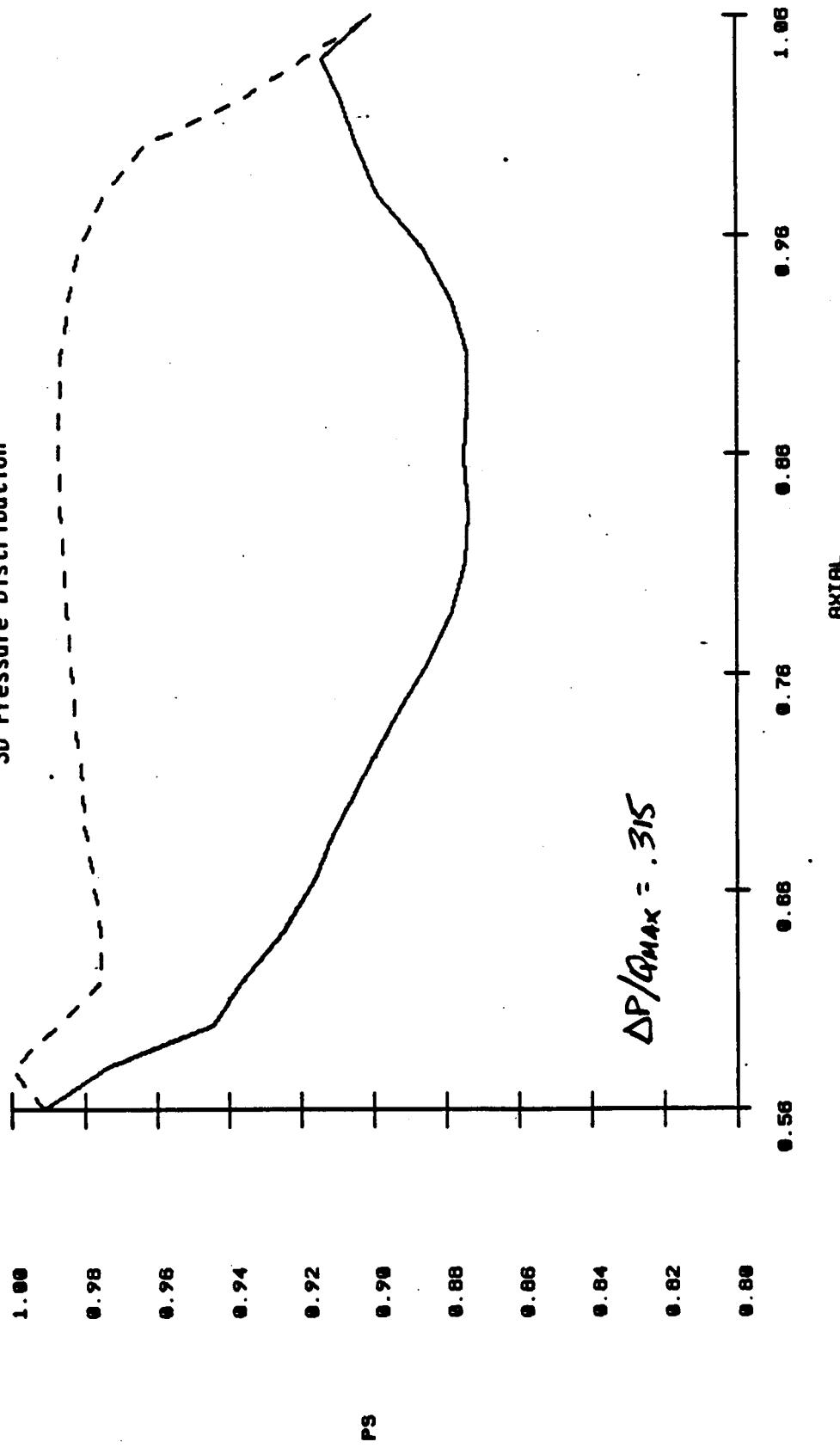
100

%

DF117436

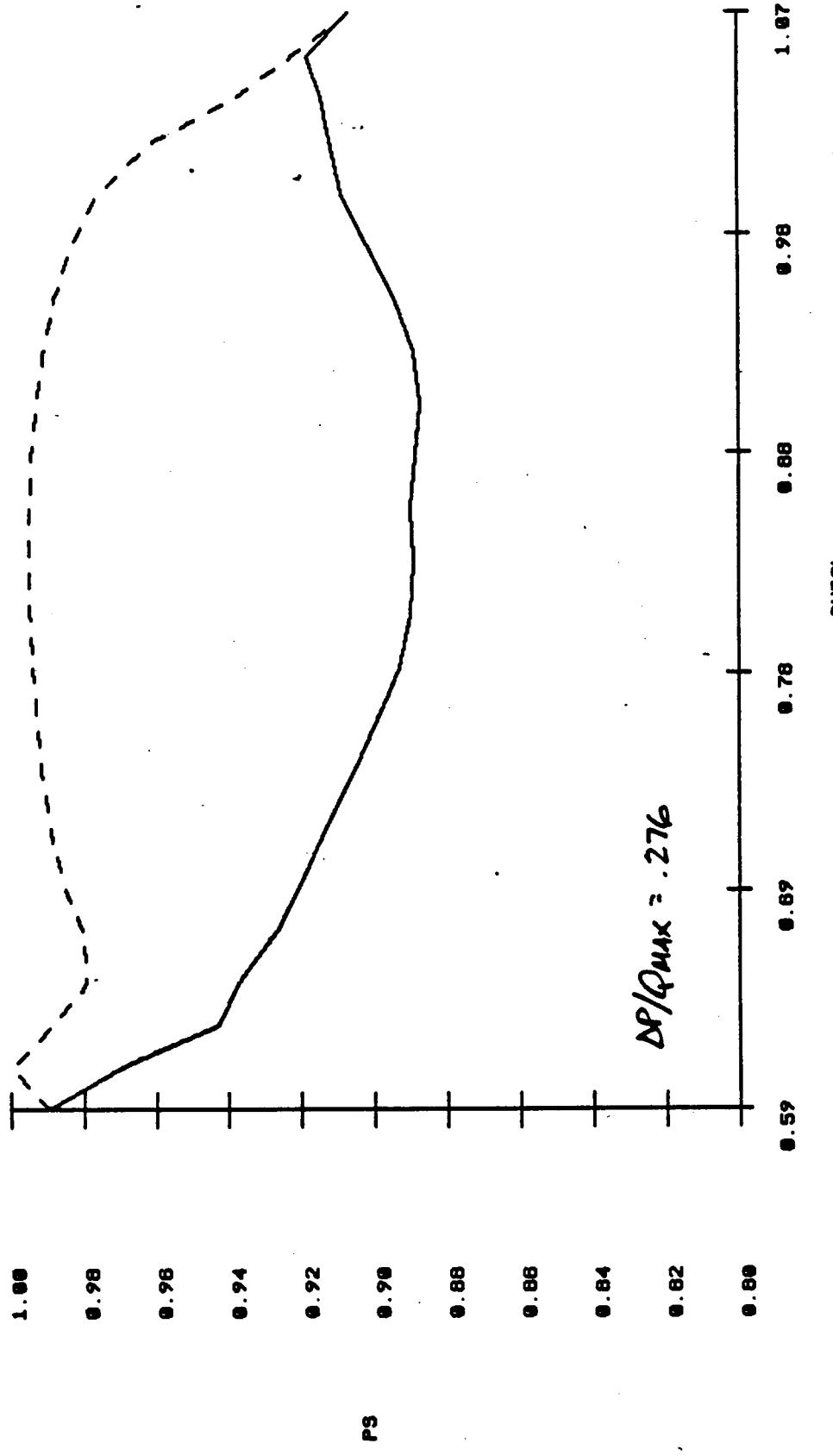
35

ATD Oxidizer Pump Turbine
1st Blade Root
3D Pressure Distribution



1. PRINT RESULTS
2. CALCOMP PLOT
3. REDEFINE X RANGE
4. REDEFINE Y RANGE
5. NONDIMENSIONALIZE
6. CONTINUE

ATD Oxidizer Pump Turbine
1st Blade 1/4 Root
3D Pressure Distribution



CURVE ITER I J K

1	0	1	0	3
2	0	9	0	3

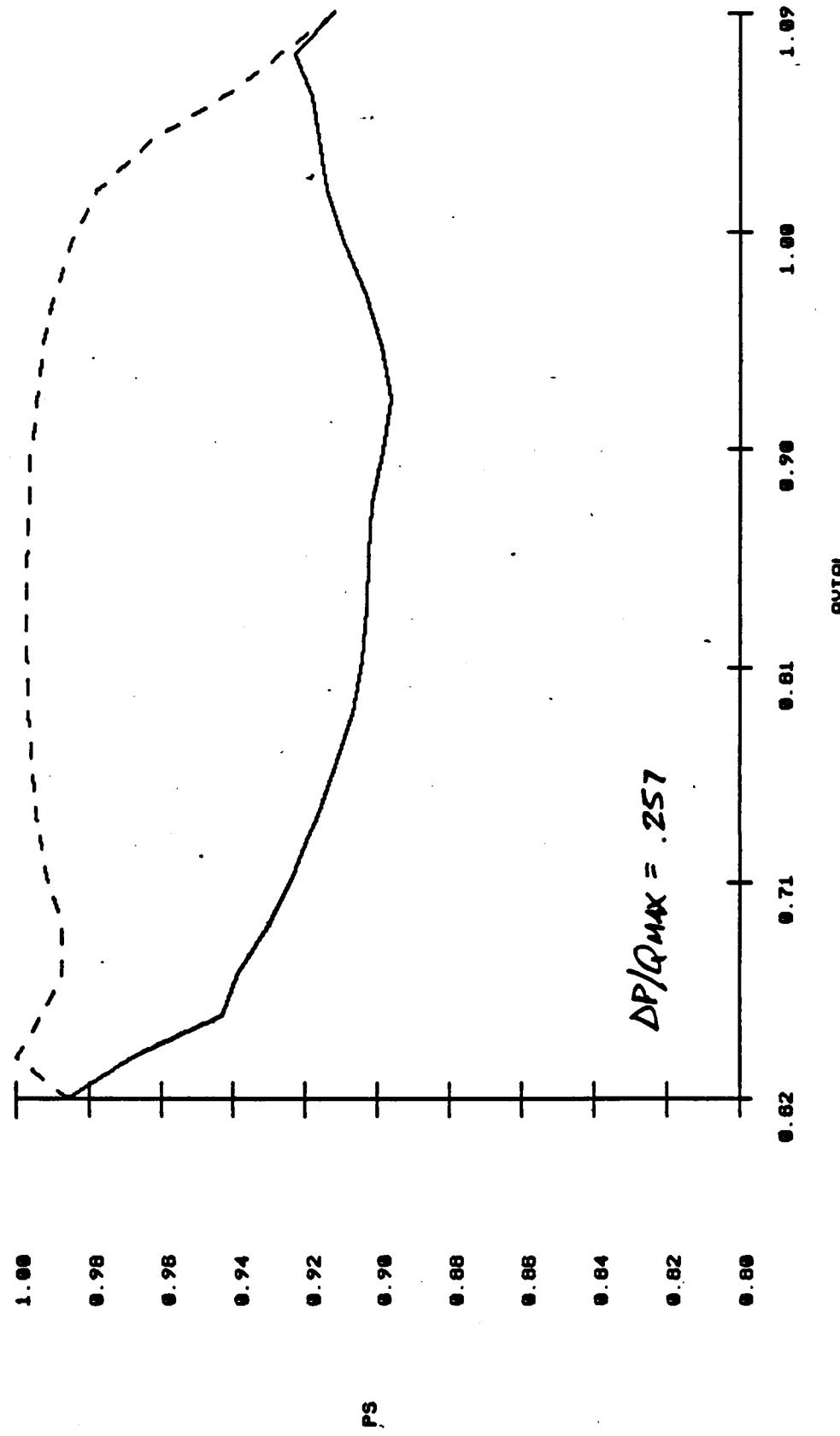
RANGE = 6 10 28

AXIAL

1. PRINT RESULTS
2. CALCOMP PLOT
3. REDEFINE X RANGE
4. REDEFINE Y RANGE
5. NONDIMENSIONALIZE
6. CONTINUE

ENTER - DF117438-B

ATD Oxidizer Pump Turbine
1st Blade Mean
3D Pressure Distribution



CURVE ITER I J K

— 1 0 1 0 5

- - - 2 0 9 0 5

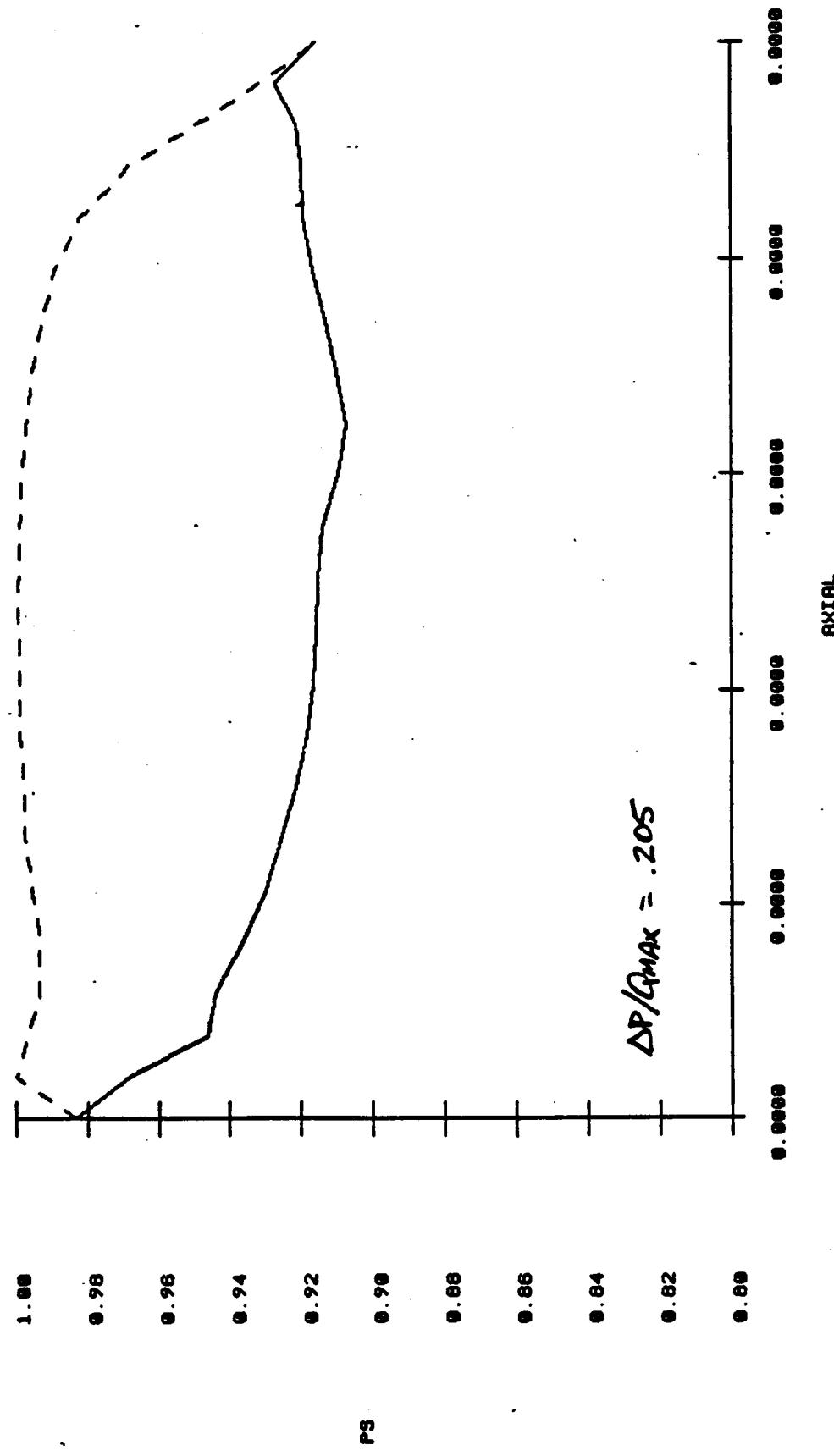
RANGE = 0 TO 26

AXIAL

1. PRINT RESULTS
 2. CALCOMP PLOT
 3. REDEFINE X RANGE
 4. REDEFINE Y RANGE
 5. NONDIMENSIONALIZE
 6. CONTINUE
- ENTER -

DF117438-C

ATD Oxidizer Pump Turbine
1st Blade 1/4 Tip
3D Pressure Distribution



CURVE ITER I J K

— 1 0 1 0 7

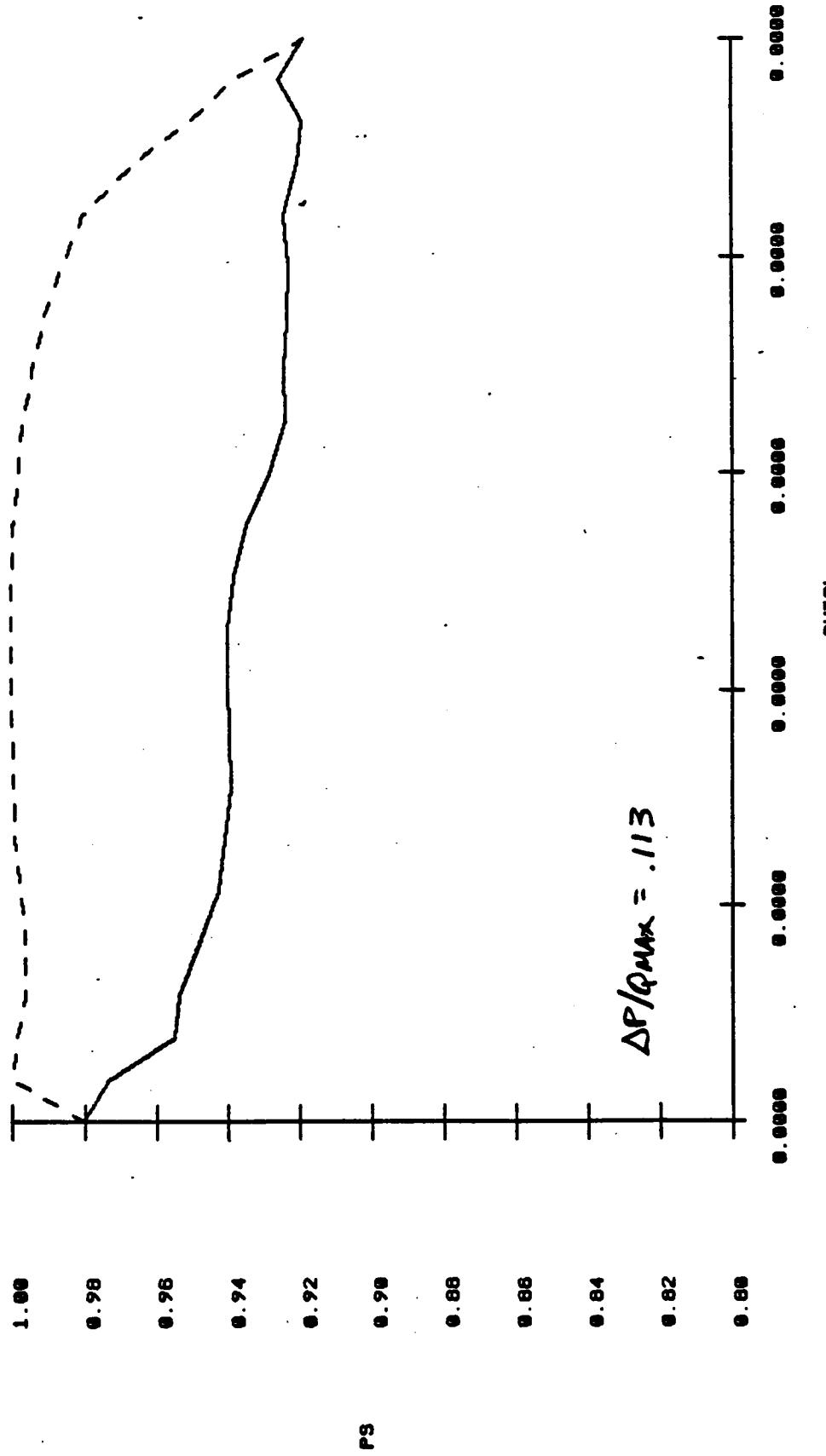
- - - 2 0 9 0 7

1. PRINT RESULTS
 2. CALCOMP PLOT
 3. REDEFINE X RANGE
 4. REDEFINE Y RANGE
 5. NONDIMENSIONALIZE
 6. CONTINUE
- ENTER -

DF117438-D

1 B Tip

ATD Oxidizer Pump Turbine
1st Blade Tip
3D Pressure Distribution



1. PRINT RESULTS
2. CALCOMP PLOT
3. REDEFINE X RANGE
4. REDEFINE Y RANGE
5. NONDIMENSIONALIZE
6. CONTINUE

ENTER -

DF117438-E

U456 - FINITE TRANSITION INTEGRAL BOUNDARY LAYER DECK

DATE 08/11/87 TIME 08:32:45
 PROJ ID B760 J. R. ROMBY IBK1 5322.20 1ST EMBODIMENT
 ROLL 4.70 RIE 4.70

4.00% TD INLET EXIT
 MACH NO. 0.222 0.359
 GAS ANGLES 30.17 14.13

SUCTION SIDE

REF. REYNOLDS NO. 9896758

0.0100

0.0090

0.0080

0.0070

0.0060

0.0050

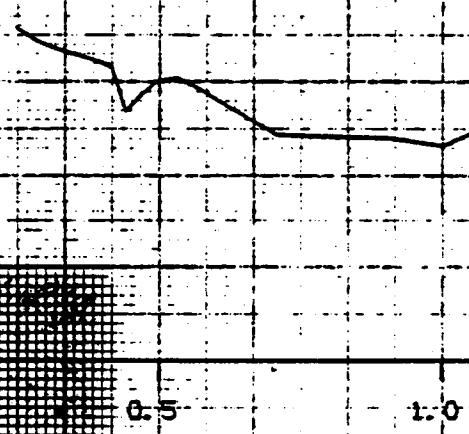
0.0040

0.0030

0.0020

0.0010

0.0000



S DISTANCE (INCHES)

TRANSITION CHART

S DISTANCE (INCHES)	0.0	0.5	1.0	1.5	2.0
---------------------	-----	-----	-----	-----	-----

DF117437-A

DATE 08/13/87

TIME 11:14:00

RJROXID U760... R. J. ROWEY 1BK3 5318 25 1ST BLADE 44 ROOT
 PLE= 4.84 RTE= 4.84

4.0024 10

INLET

EX1

MACH NO. 0.207 0.343
 GAS ANGLES 28.57 13.60

SUCTION SIDE

REF. REYNOLDS NO. 6514960.

0.0100

0.0090

0.0080

0.0070

0.0060

0.0050

0.0040

0.0030

0.0020

0.0010

0.0

0.5

1.0

1.5

2.0

S DISTANCE (INCHES)

TRANSITION CHART

0.0

0.5

1.0

1.5

2.0

S DISTANCE (INCHES)

DF117437-B

U456 - FINITE TRANSITION INTEGRAL BOUNDARY LAYER DECK

DATE 08/13/87 TIME 11:16:35

PROKID U769, J. P. ROWLEY 1BKS 5313.60 1ST BLADE MESH

RATES 5.97 RTF= 4.99

4.00% TU

INLET

EXIT

MACH NO. 0.193 0.336

GAS ANGLES 27.68 16.58

SUCTION SIDE

REF. REYNOLDS NO. 8677207.

0.0100

0.0090

0.0080

0.0070

0.0060

0.0050

0.0040

0.0030

0.0020

0.0010

0.0000

0.0

0.5

1.0

1.5

2.0

S DISTANCE (INCHES)

TRANSITION CHART

0.0

0.5

1.0

1.5

2.0

S DISTANCE (INCHES)

DF117437-C

U456 - FINITE TRANSITION INTEGRAL BOUNDARY LAYER DECK

DATE 05/11/87

TIME 08:45:18

PROXIB U456 : R. J. BERRY : 1BK7 5307.95 1ST BLADE 44 TIP

RIF = 5.17 RIE = 5.13

4.00% TU

INLET

EXIT

MACH NO. 0.175

0.319

GAS ANGLES 27.39

17.67

SUCTION SIDE

REF. REYNOLDS NO. 8877737

0.0100

0.0090

0.0080

0.0070

0.0060

0.0050

0.0040

0.0030

0.0020

0.0010

0.0000

EFT. CNT.

0.0 0.5 1.0 1.5 2.0

S DISTANCE (INCHES)

TRANSITION CHART

0.0 0.5 1.0 1.5 2.0
S DISTANCE (INCHES) DF117437-D

U456 - FINITE TRANSITION INTEGRAL BOUNDARY LAYER DECK

DATE 08/11/67

TIME 08:18:42

PROXIB U456 12 BLADE TIP IBK9 5304.45 12 BLADE TIP

DRIFT

S.R.T.

4.002 TO

5.27

INLET

EXIT

MACH NO. 0.153

0.305

GAS ANGLES 27.08

20.72

REF. REYNOLDS NO. 5964541

SUCTION SIDE

0.0100

0.0090

0.0080

0.0070

0.0060

0.0050

0.0040

0.0030

0.0020

0.0010

0.0000

FIRE CHAMBER

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

S DISTANCE (INCHES)

TRANSITION CHART

0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

S DISTANCE (INCHES) DF117437-E